FAST GROWING TIMBER TREES
OF THE LOWLAND TROPICS

No. 3

THE ARAUCARIAS

Compiled by O. O. Ntima

COMMONWEALTH FORESTRY INSTITUTE
DEPARTMENT OF FORESTRY
UNIVERSITY OF OXFORD

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0.0 PREFACE

Mr. O.O. Ntima, formerly a Forest Research Officer on the staff of the Department of Federal Forest Research in Nigeria, compiled volume 3 of the Fast Grown Timber Trees of the Lowland Tropics.

It was decided to review all species in the genus and to give full data for those which show the greatest promise within the humid lowland tropics.

Recent work on the large seeded members of the genus gives reason to hope that with suitable packing techniques and rapid transport by air it will be possible to deliver such seed across the tropics in a condition that will result in much higher germination percentages than have been obtained in the past. Nevertheless the cost will be high and it would be advisable for each interested receiving country to lay down a sufficient area to form a seed stand in the future.

This booklet is designed to help the forest officer in the field by making available to him in one volume the extent of existing knowledge on these potentially valuable timber trees. The details of all wood properties have been collected in Chapter 6 because the major species closely resemble each other and this gives better opportunities for comparison of one with another.

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Senior Research Officer.

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1.0 BOTANICAL NOMENCLATURE

1.1 Family Araucariaceae

The ARAUCARIAS are gymnosperms, a group of flowering plants in which the seeds are not enclosed in an ovary and often described as 'naked' seeds. They belong to the plant family Araucariaceae in the order CONIFERALES. This family consists of conifers which are not botanically considered as Pines although they are called Pines. ARAUCARIACEAE consists of members which may be either monoecious (i.e. having the male and female flowers on different parts of the same plant) or dioecious (i.e. having the male flower on one plant and the female on another plant of the same species). Technically the flowers should be termed strobili.

There are two genera in ARAUCARIACEAE. These are Agathis and Araucaria. To a superficial observer the two are alike. But Agathis can be distinguished from Araucaria by usually having flat and broad leaves, monoecious flowers and solitary male strobili; the cone is subglobose to ovoid and, more important, the seed is free with an unequal wing. Araucaria, on the other hand, has awl-shaped or lanceolate leaves, usually dioecious flowers and the male strobili are solitary or in clusters; the seed is not free but adnate (i.e. joined) to the ovuliferous scale, either wingless or with more or less equal wings.

1.2 The Genus Araucaria

1.21 Palaeogeography of the Araucarias

McArthur (1949), in a review of the genus Araucaria in its geographical aspects has expressed the following views:

'The Araucarias have not been found in the Palaeozoic Era[1] nor even in the Triassic (225 million years ago). The first reliable fossils of these trees were found in the Lower Jurassic (160-180 million years ago). The section Eutacta (see Taxonomy below) was

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[1] Geological history is divided into major subdivisions called eras and smaller subdivisions called periods. These divisions have reference to stages in the evolution of animals and plants from the earliest period in which recognisable fossils occur in the rocks.

found in the Lower Jurassic of Peninsular India, Northeast Australia, New Zealand and Graham Land. In India and New Zealand this section survived until the end of the Mesozoic (135 million years ago). In South Africa the only known occurrence of Eutacta was at the end of the Mesozoic. It was apparently about this time that the section spread to Patagonia where it persisted until at least the Eocene Period (60,000,000 years ago).

The section Colymbea (see Taxonomy below) is first known in the Middle Jurassic of New Zealand and New South Wales. In the former the Colymbea survived until the end of the Mesozoic and a few specimens have been found in the Eocene sediments of Western Australia and Tasmania. From the end of the Mesozoic the Colymbea are known in Patagonia, Tierra del Fuego and Southern Chile.

There was also wide distribution of Araucaria north of the Equator. Fossil remains have been found in the Jurassic beds of England and Europe and the Cretaceous beds of Dakota and Wyoming in America.'

McArthur pointed out that towards the end of the Cretaceous period (70-80 million years ago) there was an almost world-wide period of volcanism and that it was possible that the large amount of dust and ash which covered the country would have killed the vegetation. He expressed the view that this may explain why the Araucarias of certain areas disappeared in the Upper Cretaceous just as the dense fern and lycopod jungle of the Carboniferous Period suddenly disappeared at the end of the Palaezoic Period when there was also widespread volcanism. (See also para 2. 34 for views on the dynamic status of the Araucaria forests.)

1.22 Taxonomy

Botanists have divided the genus Araucaria into three main sections although opinion on this is still divided. These sections are:

a) COLYMBEA - characterised by flat or broad leaves, large cones, two cotyledons which remain below ground in germination (hypogeal). This section include Araucaria araucana, A. bidwillii and A. angustifolia.

b) INTERMEDIA x/ - juvenile leaves awl-shaped; adult leaves flat and broad; cotyledons 2-4 and are pushed above ground in germination (epigeal). Included in this section is A. hunsteinii (Syn. A. klinkii).

x/ This section was proposed by White (1947). There has been disagreement among botanists about placing A. hunsteinii in either of the sections (a) and (c) because in some essential features A. hunsteinii resembles members of the section Colymbea and in other characters it resembles those of Eutacta.

c) EUTACTA - leaves awl-shaped and curved, cones relatively small, cotyledons 2-4 and are pushed above ground in germination. Members of this section include A. balansae, A. beccarii, A. bernieri, A. biramulata, A. cunninghamii, A. columnaris, A. excelsa, A. heterophylla, A. humboldtensis, A. muelleri and A. rulei.

1.23 Distribution

The Araucarias are evergreen coniferous trees confined today to the Southern Hemisphere. They occur in South America, Australia, New Guinea, New Caledonia, New Hebrides and Norfolk Island, under tropical, sub-tropical and temperate climates. The Araucarias are noted for their long, straight and clear boles; many have useful timbers and some are cultivated as ornamental trees (Streets, 1962).

1.24 Description of three important species, A. angustifolia A. cunninghamii and A. hunsteinii (Syn. A. klinkii)

Dallimore and Jackson (1923, 1966) have distinguished between the three Araucarias as follows:-

1.241 A. angustifolia

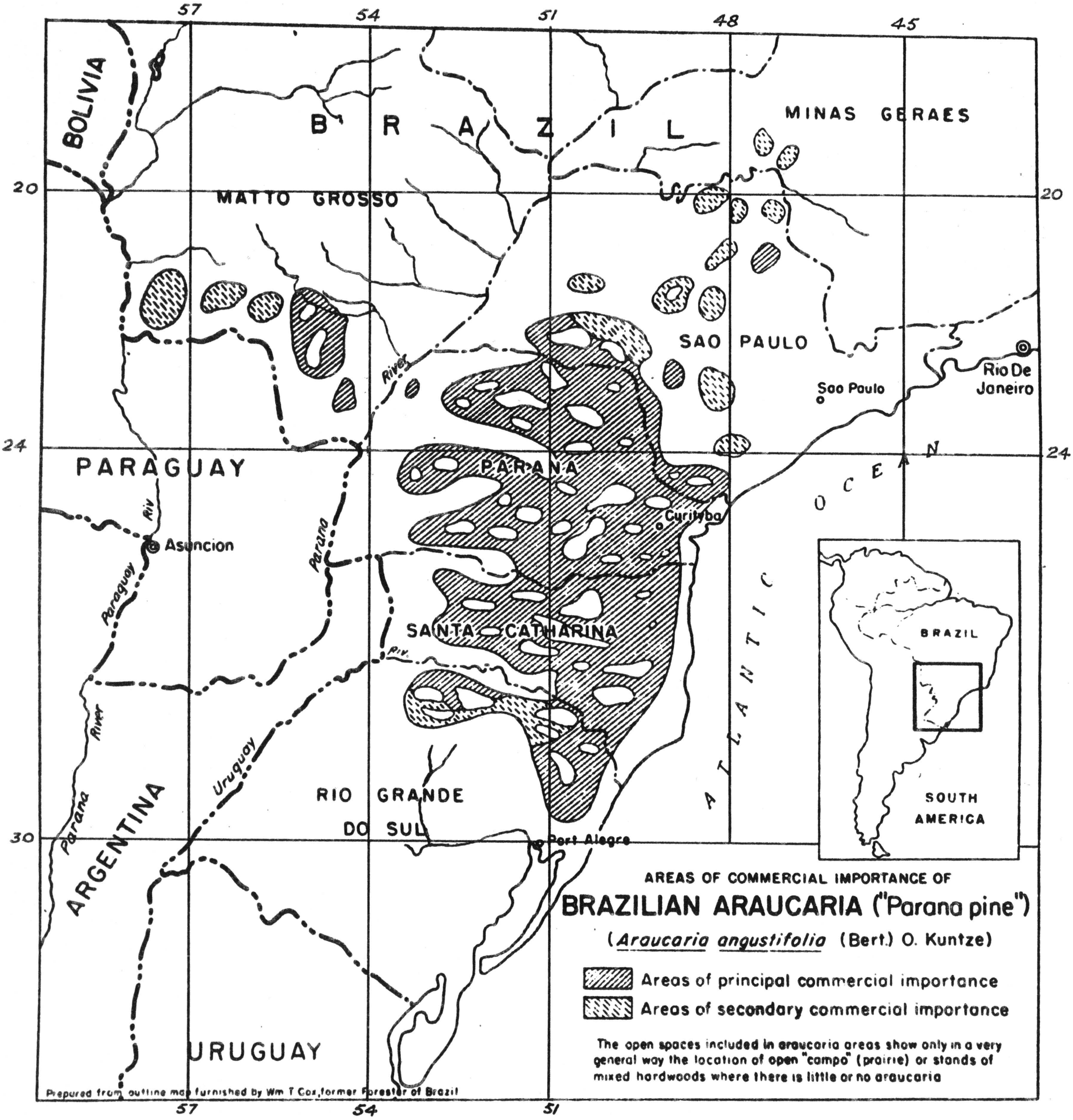
Branches: usually arranged in whorls of 4-8.

Leaves: green or glaucous, lanceolate on sterile branches, 1.25-2.5 inches (3.2-6.4 cm.) long and up to 0.25 in. (0.6 cm.) wide; sometimes appearing as if in pairs; on the fertile branches leaves are shorter, more densely and spirally arranged and in each case are long, pointed, stiff and leathery.

Flowers: Male strobili dense, measuring 3-4 in. (7.6-10.6 cm.) long, 0.5-0.75 in. (1.3-1.94 cm.) wide and usually found in the axils of short shoots.

		Female cone is broader than long, 5 in. (12.7 cm.) high and 6.5 in. (16.5 cm) in diameter, narrowed from the middle upwards.
	Scales:	terminated by stiff, recurved appendages.
	Seed:	bright brown, up to 2 in. (5 cm.) long, 0.75 in. (1.9 cm.) broad and 0.66 in. (0.84 cm.) thick.
1.242	A. cunninghamii	
	Branches:	long, with branchlets concentrated in dense tufts near the point.
	Leaves:	are of two kinds, those on young trees (juvenile leaves) and lateral branches are spirally arranged, usually lanceolate or triangular, 0.66-0.75 in. (1.68-1.9 cm.) long, straight, spreading, sharp pointed, green or glaucous with entire margins; those on the older trees and coning branches are shorter, crowded, overlapping, incurved and short pointed.
	Flowers:	Male and female usually on separate trees; male catkin 2-3 in. (5-7.6 cm.) long. Female cones are ovoid, symmetrical about 4 in. (10.2 cm.) long by 3 in. (7.6 cm.) wide.
	Scale:	Broadly cuneate with a long and awl-like reflexed apex.
	Seed:	With membranous wing on each side about 0.25 in. (0.63 cm.) long, brown and oblong in shape.
	Fruit:	Ovoid or almost spherical cones, 2-4 in. by 2-3 in. (5-10.2 cm.) long by (5-7.6 cm.)broad.
1.243	A. hunsteinii (Syn. A. klinkii)	
	Branches:	generally in whorls of five.
	Leaves:	2-5 in. (5-12.7 cm.) long, awl-shaped with adult leaves flat and broad, clustered towards the end of the branches.

15 year-old **Araucaria angustifolia** in Puerto Piray, Misiones, Argentina.
Photo : Institute de Botanica, INTA,
Castelar, Argentina.



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U. S. Dept. of Agriculture, Washington, D. C.

Cones: measure 6 by 4 in. (15.2 by 10.2 cm.) to 7.5 by 5 in. (19 by 12.7 cm.) when fully mature.

Seed: Seed scales of a mature cone are leathery, golden brown in colour and it is the product of the fusion of the seed and the bract and extends laterally into papery wings ending in a thickened umbo (Havel, 1965). Within the leathery outer cover is the seed proper, with large starchy endosperm and a cigar-shaped embryo which measures about 16 mm. long at maturity, and the seed itself measures about 20 mm. long by 8 mm. wide.

2.0 ARAUCARIA ANGUSTIFOLIA (BERT.) O. KUNTZE

(Syn. A. brasiliana A. Rich)

2.01 Local Names

Candelabra tree, pino, pinho, pinheiro, pino blanco, pino colorado, vermelho, cury, curiy and kuriy.

2.02 Trade Names

Parana Pine, Parana Wood, Brazilian Pine.

2.1 Distribution

(See map).

A. angustifolia is naturally confined to the southern states of Brazil, particularly in the hilly province of Parana where it reaches its best development and from where it gets its local names. It also occurs in Santa Catarina, Rio do Sul, Matto Grosso, Sao Paulo, Minas Geraes and in small areas of forests in Paraguay and in the state of Misiones, Argentine (Brush, 1945). The tree also occurs scattered in the mountains of Rio de Janeiro, Espirito Santo and Bahia. While its botanical range, in South America, is thus from 18^{o} to 30^{o} South latitude, its commercial range lies between latitude 22^{o} and 28^{o} South (Brush, op. cit.).

A. angustifolia occurs in commercial quantities in the plateau region of the six Brazilian states mentioned above but in the northern part of its range (which probably represents escape from cultivation by early settlers) it does not occur below elevations of 2,500' (762.4 m.) above sea level. It may be found at lower elevations as its southern range is approached but is nowhere below 1600 ' (487.9 m.), (Rogers, 1953).

2.2 The Tree

The leaves, flowers and branching habit of A. angustifolia have been described in paragraph 1.241. But the following gross morphological features should be noted also.

Parana Pine is a sub-tropical conifer, a moderate to large-sized tree, varying in height at maturity from 80' to 120' (24.38 m. to 36.58 m.).

Bole: Long, straight and clear, often as much as 50' (15.24 m.) in length.

Bark: Thick and ridged horizontally, resinous.

Crown: Flat topped at maturity; when growing in open situations the tree is said to resemble the Chile Pine (A. araucana) "Monkey Puzzle". As the tree matures in forest conditions, the habit changes, the side branches being suppressed and lost and those of upper whorls turning upwards to the light in the manner often referred to as 'candelabra' shaped, hence its local name.

Diameter: In mature stands the diameter averages 2' (0.61 m.); on the plateau of Santa Catarina it is reported to have reached 15.75-19.69 in. (40-50 cm.) d.b.h. in 50 years.

2.3 Habitat Conditions

2.31 Climate

2.311 Rainfall

Parana Pine is a species of sub-tropical to temperate climate but the northern part of its range lies wholly within the tropics; the altitude at which it occurs modifies the climate. Over the whole area of its distribution the average annual rainfall is good - between 50 and 87 in. (1270 mm. and 2210 mm.) distributed uniformly throughout the year. It does not tolerate a severe dry season. However, while Parana Pine can be successfully grown in areas with rainfall pattern similar to the natural site of the species (i.e. where rainfall is uniformly distributed throughout the year and without a severe dry season) it also has limited prospects of growing well in areas with summer rainfall and dry winters (Golfari, 1963). For example, although the species comes from Brazil in areas where rainfall is uniformly distributed it can also live further north in small mountain patches in Sao Paulo and Minas Geraes with summer-rains and fairly humid winters.

2.312 Temperature

Although this ranges from the hottest extreme (January) of 35°C (95.0°F) to the coldest month (July) of -6°C (21.2°F) at 3000' (914 m.) in the northern part of its range, the temperatures which are of most importance are the absolute minimum and the mean minimum for the coldest month (Rogers, op. cit.). It requires a mean temperature in the coldest month between 8°C and 14°C (46.4°F and 57.2°F) and a mean temperature in the hottest month of between 18°C and 24°C (64.4°F and 75.2°F). Absolute minimum temperature must not be below -12°C (10.4°F). A. angustifolia is accustomed in its natural habitat to an annual mean temperature of 10°C (50°F) to 18°C (64.4°F), but it has been grown successfully in Misiones, Argentina, outside its natural range in areas with a temperature of 20°C (68°F).

Golfari (1963) has given the following climatic data for Parana and Hoop Pines. In general, he points out that a comparison of such climatic features should provide a good basis for ascertaining whether a species is likely to succeed in a specific area.

Climatic Data for A. angustifolia and A. cunninghamii

Species (1)	High Mountain (or cold temperate) Mean temperature of coldest month (MTCM) (2)		Low Mountain (or temperate) Mean temperature of hottest month) (MTHM) (3)		* Absolute minimum temperature (4)		Mean annual precipitation (5)	
	°C	°F	°C	°F	°C	°F	mm	ins
A. angustifolia	8-14	46-57	18-23	64-74	-8	17	1250-2200	49-86.6
A. cunninghamii	9-16	48-61	20-26	68-79	-6.5	20	1000-1500	39.4-59

* The figures in this column refer to the absolute minimum for each species recorded in its natural site (Golfari, op. cit).

Other factors which should be taken into account when introducing species into a new or different environment are (apart from rainfall and temperature) relative humidity, light intensity and duration, depth, texture, drainage, slope and reaction of soils. Biotic conditions and influences are also important.

2.313 Frost

The adult tree of Parana Pine is frost-resistant but the seedlings are killed by severe frost. Both the severity and range of occurrence of frosts have an important bearing on the survival and growth of young seedlings.

2.32 Edaphic Factors

A. angustifolia grows on a variety of soils derived from granites, basalts, diorites, phyllites, sandstones, schists and slates. It can survive on poor and shallow soils. The amount of plant food available in the soil plus the ability of the soil to retain moisture, appear to be of greater importance than soil texture. Because of its long taproot, deep fertile soil is very essential for optimum growth; otherwise the plants very often die all at once after 6-8 years when the roots reach stony layers or hardpan (Rys, 1949). Parana Pine requires good drainage.

2.33 Physiographic (topography) Factors

Since A. angustifolia reaches its best development in the plateau areas of Parana State, Brazil, it is reasonable to say it thrives best on hilly regions where conditions are favourable. It has invaded parts of the Brazilian highlands where the prairie vegetation predominated. Parana Pine is not suited to low-lying areas containing frost hollows.

2.34 Ecological Associations

In its native habitat Parana Pine does not occur in pure forests. For example in Northern Parana, the forest consists of an upper storey of pine and a second storey of rainforest species such as Cedrela, Aspidosperma, Nectandra and Phoeve perosa. A third storey of fairly dense undergrowth of various woody shrubs is also discernible, but with an almost complete absence of small-diameter Pine and Pine regeneration. Towards southern Parana, the forest consists in places almost purely of Pines of all sizes, with practically complete absence of rain-forest trees and only light undergrowth. At higher elevations and higher rainfall areas of Rio Grand do Sul the forest becomes much denser, both Pine and rainforest trees of large diameter being common; there is also a good distribution of all diameter classes of Pine from regeneration to the biggest sizes. Tree ferns, bamboos and the famous Brazilian tea, Ilex paraguensis, form the ground layer. Within the Parana Pine stand there are frequent openings which may consist of grassland or "campo".

Recent studies by Klein (1960), of the natural A. angustifolia forests have revealed interesting facts concerning the dynamics of these forests in general and the behaviour of A. angustifolia in particular. Klein is of the opinion that there has been a recent change in climate, in the Quaternary, in the south of Brazil, a change which has made a profound impact upon the vegetation, resulting in the creation of a favourable forest climate.

Klein claims that previously the climate was predominantly colder and drier in the Brazilian highlands with the result that the prairie vegetation predominated. But gradually shrubs and trees began to invade the prairie and among the trees was A. angustifolia, a light demander and pioneer species. This invasion of the prairie was kept in check by man's interference through annual burnings. Otherwise, it is thought, the expansion of Araucaria on the prairie of South Brazil would have continued uninterrupted. But where Araucaria stands were left undisturbed some hardwood and shade tolerant species came in because A. angustifolia had created favourable forest conditions for them. Foremost among these hardwoods were members of the family Lauraceae. In time these shade tolerant species gradually replaced the light demanding A. angustifolia except at the periphery of the forests because of insufficient light under the hardwoods for the regeneration of the latter. As a result only old Parana Pine trees are found in the interior of the forests. These are Klein's views. He thinks that his conclusions would be important because, if A. angustfolia is a pioneer species, it would be of great value to the forester in trying to design silvicultural techniques suitable for the proper and successful regeneration of Parana Pine, naturally or artificially.

But a view different from the above has been held by Frith (1966) who has made a study of Parana Pine distribution in Misiones. Frith has found evidence that the distribution of Parana Pine can be correlated with the shifting cultivation and migration of the local people. He considers that it could grow at low altitudes but is unable to regenerate in high forest shade. It has been distributed by migrant Indians who used the seeds for food and is found where they have made clearings round settlements at low altitudes. It is wide-spread at higher altitudes because the Indians prefer to live in such cooler and less malarial climates. Frith argued that if Parana Pine has the same need for high nitrogen availability in the soil as Hoop Pine (A. cunninghamii) and if, as is well known, the seedlings are fire tender then it could not be a pioneer species on open savannas as suggested by Klein, but a second-growth species in cleared high forest. The author thinks Frith's view is more likely to be the correct one than Klein's if Parana Pine's behaviour and requirements resemble those of A. cunninghamii in Queensland q. v.

2.35 Special Biotic Considerations

Parana Pine is edible and is readily eaten by pigs and also large quantities are gathered for food. Seed and seedlings are not apparently damaged by grazing cattle but seedlings of 5' (1.52 m.) or more in height are severely damaged and in most cases killed by horses and donkeys browsing on the bark (Rodgers 1953).

2.36 Effect of Fire

Seedlings of A. angustifolia are easily killed by fire but trees of 15.75 in. (40 cm.) or more in diameter are reported to be fire resistant.

2.37 Mycorrhizal association

Milanez et al (1950) have observed the presence on A. angustifolia of short, more or less spherical, rootlets, whose cortical cells were filled with mycorrhizal hyphae. It was noted that the endophyte never invaded the central cylinder from which it was limited by tannin-cells of the endodermis. The investigators expressed the view that it would be useful to establish the importance of this endophyte in the ecology and silviculture of Parana Pine. The evidence of the occurrence of mycorrhizae on A. angustifolia is confirmed by Oliveira and Ventura (1952).

2.4 Life History and Development

2.41 Flowering and Fruiting

In its native habitat, A. angustifolia flowers and fruits regularly. The flowers are dioecious. The age at which flowers appear has been variously reported, but in Kenya (outside its natural home) trees of 13 and 15 years old in the East African Agricultural and Forestry

Research Organization (E. A. A. F. R. O.) arboretum are reported to be bearing seeds.

2.42 Seed Production

Seeds are regularly produced annually in its native home. In Brazil the seed matures from late April to late May. In Kenya the seed fall occurs about May-August, East of the Rift, but it has been reported that the seed has been shed in April, West of the Rift (Wormald 1967). The cones are said to take two or three years to ripen and about 50 seeds per lb (110 per kg.) have been recorded. The seed is heavy, egg-shaped and rather more pointed where it is attached to the cone. The outside end has a thickened wing. The seed coat is tough and leathery.

2.43 Seed Quality - Storage and Germination

Parana Pine seed does not retain its viability long, not longer than six weeks when stored at atmospheric temperatures. It is probable that the viability of seeds improves as the mother tree gets older. The seed can take a long time to germinate. From Tanzania it is reported that seeds stored for four and nine months took 105 and 101 days respectively to germinate.

Because of its short viability seed should be sown within a month of collection. It is recommended that seeds should be stored in plastic bags rather than in glass containers on economic and management grounds. However there is no difference statistically in germination per cent between seeds stored in glass containers and those stored in plastic bags (Prange 1964). Pasztor (1962/63) has found that the germination per cent of embryos excised within seven days from dry seed is a reliable indicator of the germinative capacity of a given seed-lot of A. angustifolia; also this method was found to be the least injurious to the embryos. From the results of a series of experiments, Cozzo (1962), is of the opinion that seed size is a better criterion in the selection of good quality Parana Pine seed than the floating test.

2.44 Seed Dissemination

The seed is heavy and it is therefore not easily dispersed by the usual agents of wind and birds. But being edible it is dispersed by animals (at least those which escape being eaten) and man.

2.45 Seedling

An important point to remember is the root system of the seedling of Parana Pine. In the seedling stage the taproot is very long in relation to the height of the seedling above ground; there is also a complete absence of lateral roots on the upper section of the taproot. A knowledge of the nature of the kind of taproot of A. angustifolia seedling is fundamental to a proper understanding of its nursery technique. Lack of this knowledge and hence inappropriate nursery technique has led to disastrous results, for example in Kenya.

2.5 Silviculture

Parana Pine is an example of a species which has long been over-exploited without much thought for its future survival either through planned forest management, natural regeneration or conscious planting. For this reason great concern has long been expressed about its future and there are indications that within a few years those forests that once covered great areas in Southern Brazil will be extinct unless they are regenerated by modern silvicultural methods and management practices, (Berenhauser 1966).

2.51 Natural Regeneration

The ecological status of A. angustifolia has been outlined in section 2.34. From this and from the little knowledge that exists concerning its silviculture, it can be stated that Parana Pine under suitable conditions regenerates naturally. This system might be used successfully in the southern part of its range, but earlier reports tend to indicate that natural regeneration has not been attempted with much success. This is largely because its silvicultural requirements and peculiarities have still not been sufficiently studied. Nevertheless some important points regarding its silvicultural characteristics have been observed and are summarised as follows (Rogers, op. cit).

(i) Parana Pine is a strong light demander which does not develop under forest shade. However the author's view that it is not a pioneer species may explain why attempts at natural regeneration of savanna areas have failed, as reported by Rogers.

(ii) Its growth rate under shade is therefore slow.

(iii) Most natural seedlings have been observed to occur in groups in openings made by the removal of trees, along roads and along the edge of forest. In other words, the seedlings are found wherever there is ample overhead light and no fire.

(iv) In its native area there is a regular and seasonal seed-fall each year.

(v) The seed is readily eaten by pigs and large quantities are collected for food; seed and seedlings are not damaged by grazing cattle but saplings of 5' (1.5 m) and above are damaged by browsing animals.

(vi) Seedlings and saplings are easily killed by fire although older trees are fire-resistant.

2.52 Artificial Regeneration

Reforestation with A. angustifolia is a relatively new forestry activity in Brazil. This is because of the presence in the past of abundant natural stands of A. angustifolia which were thought to be inexhaustible. In fact reports indicate that, to date, reforestation is replacing less than 1% of the timber which is cut annually (Berenhauser op. cit). Earlier plantings undertaken with Parana Pine were unsatisfactory probably because of a lack of knowledge concerning its silvicultural characteristics. However, plantings of A. angustifolia outside Brazil had been carried out in various parts of the world. Readers interested in the performance of Parana Pine in various parts of the Commonwealth should refer to Streets, (1962).

2.521 Seed
(see para 1.241)

2.5211 Seed Trees

In its natural habitat an average Parana Pine tree is a tree of reasonably good form. But it has been found that in certain regions of the forest numerous trees may develop epicormic shoots. Opinions differ as to the cause of this type of unusual crown development; some people have suggested that this type of branching habit is characteristic of soils of low pH and young forest, others consider the shoots to be the result of insect or fire damage some years ago, and there are those who think that this branching habit may be hereditary. Until more is known about the causes of these unusual branch forms, seed should be collected from parents free of epicormic branches, and with well developed boles and crowns.

2.5212 Seed Collection

For the timing of seed collection see A. cunninghamii and A. hunsteinii. Seed should be collected from freshly fallen cones.

2.5213 Treatment of Seed

In Brazil it is usual to subject the seeds after collection to a floatation test to screen off bad and infertile seeds. This is done by placing the seeds in wooden barrels of 100 litre capacity (22 gall.) containing water in which Granosan, a fungicide, has been dissolved at the rate of 150 gm. per 100 litres (about 5.3 oz. to 22 gall.). After two loads of seed have been treated in this way the concentration of the solution is maintained by the addition of another 50 gm. (1.8 oz.) of Granosan. If it is necessary to treat 5000 kilograms (11,020 lbs.) of seed, 8 tins each of 450 gm. (15.9 oz.) of fungicide are required. Good seeds are placed on a screen to dry and when thoroughly dried, the seeds are bagged.

Objection to the floatation test as a means of determining seed quality has been raised by Cozzo (1962), who has expressed the view that seed size is a better criterion in the selection of good quality Parana Pine seed than selection by the floating test.

2.522 Direct Sowing

In Brazil itself the earliest plantations initiated by private commercial concerns were established some 45 years ago. The early method of establishment was by direct seeding on areas previously prepared. No attempt was made to establish plantations by the use of plants raised in the nursery.

In this method of direct seeding, A. angustifolia seeds were sown on previously ploughed or unploughed land which has been prepared by brushing and burning of the regrowth in April and May. On such lands, holes 4 in. x 4 in. (10 cm x 10 cm) and 6 in. to 8 in. (15 cm to 20 cm) deep were made with small digging tools such as hoes and seeds varying from one to three were placed in each hole, depending on the seed quality and the season of planting. Planting was between May and June and efforts were made to ensure that planting was completed before the end of August. Spacing varied from 3.28' x 3.28' (1 m x 1 m) to 9.84' x 9.84' (3 m x 3 m). Tendings (where they were not neglected) were done by brushing or cutting in the older plantations and by chipping with a hoe in the younger areas.

2.523 Nursery Practice and Procedure

One of the main reasons for adopting the direct seedling method in establishing the earlier plantations in Brazil was the difficulty encountered in transplanting the seedling of Parana Pine either from the seed beds to transplant beds or from seed beds direct to the plantations. This difficulty arose because of the long taproot system of Parana Pine seedling and this cannot normally be transplanted without serious damage to the taproot.

Rogers recommended the adoption of the method developed for A. cunninghamii (in Queensland, Australia) which has a taproot system similar to that of A. angustifolia.

The Queensland method is briefly as follows:-

The Queensland nurseries use high shade, giving about 50 percent light. The seed beds are 45' (13.72 m) long by 9' (2.74 m) wide and seeds are sown in September in drills 8" (20.3 cm) apart, the rate of sowing aims at a stocking of 26 seedlings per metre of drill. The timing of root-wrenching (root-pruning) is largely the result of strong tap-root development in the early life of A. cunninghamii. The object of root-pruning is to cut back the long tap-root and to stimulate the development of lateral roots. Experiments have shown that satisfactory results are obtained when the roots are pruned between the 15th and 18th month after sowing, but results obtained during this period could be considerably influenced by weather conditions following root-pruning. In Queensland actual timing of the operation in routine practice is therefore governed by the likelihood of favourable weather conditions being experienced in February when the wet season begins.

At about seventeen months after sowing the seedlings of Hoop Pine are root-pruned at a depth of 6" to 7" (15.2 - 17.8 cm) below ground level. Following root-pruning the seedlings remain in the seed beds for about five months (22 months from sowing) when they are lifted for culling, grading and tubing in tubes 9" x 1'5" (22.8 x 3.81 cm) diameter (i.e. at 2 years old). By root-pruning the plants in situ and leaving them in the seed beds for five months a callus forms over the cut surface of the taproot and the development of lateral roots is stimulated. But there is also a tendency for the rapid redevelopment of the tap-root. If root -pruning is carried out earlier than the period prescribed a further root-pruning prior to tubing would be necessary in order to control further root development and to avoid a substantial shock to the plants at the time of lifting. Decreased plant growth would result from such a long term restriction of the root system as well as an increase inthe operating nursery cost.

Seed beds are kept well watered following root-pruning. The resulting plants are well balanced in respect of crown and root and they are then tubed.

Experiments have shown that optimum early growth and best field establishment is obtained with plants which had remained in the tubes for 10-13 weeks prior to planting. If substantial longer periods are spent in the tubes loss of growth and vigour results following the restriction of the root system and the tendency for redevelopment of the taproot. In such cases there should be a need for periodic lifting or "shocking" of the tubed plants in order to control this tap-root redevelopment. This results in a reduction in growth and vigour.

The present practices in Queensland result in the production of strong and vigorous nursery stock which recover quickly from tubing and are again in an actively growing condition at the time of planting out in the field. The plants establish rapidly and are better equipped to compete with vigorous weeds.

2.5231 Construction of High-Shade in Nurseries

For the production of planting stock the following procedure has been suggested. High-shade nurseries with nursery beds measuring 50' x 10' (15.2 m x 3 m) should be established. This requires sawn impregnated posts 6" x 6" x 9' (15.2 cm x 15.2 cm x 2.74 m) long, 2'6" (0.76 m) in the ground and 6'6" (1.98 m) above ground and spaced at 12' x 12' (3.66 x 3.66 m.). On top of each post are placed caps 5" x 2" (12.7 cm x 5 cm) and usually 24.5' (7.5 m) long; at right angles to the caps are bearers each measuring 3" x 2" (7.6 cm x 5 cm) and 24.5' (7.5 m) long and spaced 5' (1.52 m) apart and at right angles to the bearers are nailed slats of 3" x 5/8" (7.6 cm x 1.6 cm) in lengths of 10' (3m) or multiples thereof and spaced 3" (7.6 cm) apart. Beds should be thoroughly dug to a depth of 9" (22.86 cm), worked to a fine tilth and edged with sawn timber 4" x 1" (10.2 cm x 2.54 cm).

In Queensland the use of plastic net shades is still in the trial stage. "Sarlon" mesh (mainly the 52% grade), is used quite extensively to date although there are some indications that the 46% grade is also producing satisfactory results. It has been used initially as a removable low shade coverage after tubing but work is in progress on its usage as both high and low shade seedling beds. Plant growth is reported satisfactory and the indications are that its usage will be extended once information is obtained on the most desirable method of suspension. Also the question of exercising some control over seed bed growth by removing or varying the shade cover during the growing period would require to be investigated.

For further notes on preparation of beds and possible pH requirements see A. cunninghamii. Some nurseries are now experimenting with plastic nets as shade instead of wooden slats.

These are lighter in weight and can be supported on a lighter frame. Sarlon plastic nets can be obtained to give a variety of shade densities.

2.5232 Sowing of Seeds

In Brazil seeds are sown in mid-May in drills 8" (20.3 cm) apart with six seeds per foot of drill. Early sowing in April to June, especially at elevations equal to or greater than 1640' (500 m), using 2 seeds per hole, has been suggested by Sanchez (1961).

The seeds should be placed in the drill with its long axis at right angles to the length of the drill, all the seeds pointing in one direction. The seeds should be covered with soil to a depth of about 1" (2.5 cm). The beds should be kept moist during the period of germination. Germination usually starts after 60 days and continues up to 105 days.

2.5233 Watering and Weeding

Weeding should commence as soon as the first few weeds appear;intensive hand hoeing particularly in the first 18 - 24 months is recommended. Depending on weed conditions and soil, it may be found necessary to cultivate the space between the drills at three-weekly intervals. Once the seedlings have become established watering should be reduced to two or three waterings per week.

2.5234 Root-wrenching
(pruning)

This should be done by means of a sharp blade so that the roots are cut at a depth of 6" to 7" (15.2 cm to 17.9 cm) below ground level. Watering, weeding and, where necessary, cultivation, should be continued as required after root-wrenching. In Brazil, for example, root-wrenching is done in mid-February and at the beginning of July the plants are lifted.

2.5235 Grading and Tubing
(See A. cunninghamii, paras 3.5238 and 3.5239)

In Kenya bamboo tubes 1.75" to 2" (4.4 cm - 5 cm) internal diameter have been recommended (for A. cunninghamii) instead of galvanized iron tubes used in Queensland . The bamboos are split open vertically into two equal halves and tied up. However, the metal tubes (made from flat sheets of 28 gauge galvanized iron 8" x 6" (20.3 cm x 15.2 cm)) have an advantage over the bamboos.

They can be re-used for up to 15 years whereas bamboo tubes can be used only once unless the two halves are kept paired after use. The metal tubes might be more economical in the long run but they cost £14A per 1000 and many nurserymen now prefer polythene pots or tubes which are cheaper and are used once only.

2.5236 Research Needed

In any country where A. angustifolia has been introduced, and also in Brazil, Paraguay and Argentina, research work into the following aspects of nursery technique should be undertaken.

> season of sowing; type and depth of seed cover; spacing in drills; season of root-wrenching; season of tubing and the type of tubing material e. g. the use of polythene tubing; period of time in the tube; watering, weeding and cultivation; types and densities of shade.

2.524 Plantation Establishment

2.5241 Site Preparation and Planting

Parana Pine will normally be planted on sites cleared of high forest or on former high forest sites which have been degraded to grassland. In the former, stump removal and ploughing will not be necessary unless there is a serious risk of death from *Armillaria mellea*, a fungus liable to spread from decaying stumps. Ploughing is commonly used to remove grass competition on grassland sites where planting is on a large scale. Best results in the first and second years on high forest sites follow a clear burn of the cut debris as near the beginning of the rainy season as possible and early planting whenever the first rains have soaked the ground. In Brazil planting is normally completed by December and in the northern tropics by the end of June or early July.

2.5242 Care of Planting Stock

Great care should be taken over tubed stock ready for planting. Unnecessary exposure to wind or drought should, as far as possible, be avoided. It may be necessary to erect a special shed for tubed stock.

2.5243 Depth of Planting

Both shallow and deep planting have an adverse effect on plant survival. But it is important to ensure that the whole root-system is below ground. The correct depth of planting is a matter for experiment.

2.5244 Spacing

For Parana Pine opinion is somewhat divided on the correct spacing. Rogers (op. cit) recommended 6'6" x 6'6" (2m x 2m) for Brazil and suggested that experiments to cover the following range would be necessary:

3.28' x 3.28'(1m x 1m), 4.9' x 4.9' (1.5m x 1.5m), 6.6' x 6.6' (2m x 2m), 8.2' x 8.2' (2.5m x 2.5m). But Filho (1957) has found that plots established in 1952 (at the Horto Experimental de Saute Rita do Passa Quatro) at spacings of (1) 3.28' x 3.28'(1m x 1m), (2) 4.9' x 4.9' (1.5m x 1.5m) and (3) 9.84' x 9.84' (3m x 3m) showed the following mean diameter increments over four years: (1) 1.2" (31 mm), (2) 1.4" (35 mm) and (3) 1.57" (42 mm). Measurements made in plots of Parana Pine after five years of growth, given initial spacing ranging from 3.28' x 3.28' (1m x 1m) to 9.84' x 9.84' (3m x 3m) had led Veiga (1957) to conclude that the ideal basal area at five years old is 54.8 - 58.2 sq. ft. (quarter girth) per acre (16-17 sq. m per hectare), and suggested that thinnings should be carried out on this basis. Correct spacing and ideal basal area will vary from place to place and even in the same area from site to site. The demand of local markets is another factor to be considered. In Kenya it has been suggested that plantations should be established at 9' x 9', i.e. 540 plants per acre (2.74m x 2.74m or 1334 plants per hectare) in really clean shambas but where these are not available spacing may be at 8' x 8' (2.44m x 2.44m) (Wormald, 1967).

2.5245 Beating Up
(Supplying)

Where beating-up is required it should be carried out as soon as possible(say, three to four months after planting) and in any event not beyond the second year.

2.5246 Tending

Correct tending in the first two years is particularly important. In the first and second years after planting this would involve the removal of undesirable weed growth, preferably by grubbing or hand pulling. The time the first tending operation commenced would be dependent on local conditions and the intensity of weed growth. Information of the frequency and cost of tending should be a matter for investigation.

2.5247 Pruning and Thinning

Little published data is available. For Brazil, Rogers (op. cit) suggested that pruning would probably not start until at least eight years and thinning not until twelve years after planting. In any case pruning and thinning would depend on the object of management. For example in Queensland, Australia, high wood quality is an objective in pruning and in New Guinea since pruning is confined to selected trees the first thinning is at the time of pruning.

Pruning prescriptions and thinning regimes developed for A. cunninghamii and A. hunsteinii should be used as a basis for work in A. angustifolia plantations (see 3.5247). In Kenya it is hoped that by pruning to ½ height a knotty core limited to 6" (15.2 cm) diameter will be achieved and the object in thinning is to give the final crop trees the maximum opportunity to put on diameter increment without sacrifice to height growth. The following interim prescription was suggested for A. angustifolia in Kenya (Wormald, op. cit):

Mean Height	Approximate Age	Prescription
20' (6.1 m)	7	Prune to ½ height
30' (9.14 m)	9	Select 280-300 stems per acre (692-741 stems per ha) and prune to ½ height
40' (12.2 m)	11	Thin to 300 stems per acre (741 stems/ha) by removing trees not selected for high pruning. Prune to 22' (6.7 m)
60' (18.3 m)	20	Thin to 135 stems per acre,(334/ha
	30	Thin to 100 stems per acre (247 per ha) removing 1 tree from each group of 4 trees
	45	Clear fell

2.6 Mensuration

2.61 Growth and Yield

A study of the growth and production of A. angustifolia in plantations revealed that the tree is a fast growing species capable of yielding, at the age of 23, a mean annual increment of stem wood over

168 cu. ft. (Hoppus) per acre (15 cu. metres per hectare), (Kissin 1950). Berenhauser (1966) has reported that on the plateau of Santa Catarina, A. angustifolia has reached 15.75-19.69 in. (40-50 cm) breast height diameter in 50 years.

2.611 Brazil

From a study of the existing plantations in Brazil, Glerum and Heinsdijk (1967) have found that the maximum average annual increment of Parana Pine pulpwood plantations is reached at 11 years of age but suggested that the rotation should be fixed at 17 years in order to produce the desired size of pulpwood material. They based their conclusion on the following table:

Possibilities of average annual growth per hectare of cultivated A. angustifolia

Age (years)	Site-class	Average annual growth per hectare m^3
4	1	-
	2	-
	3	-
	4	-
8	1	-
	2	21.1
	3	11.0
	4	6.0
11	1	-
	2	22.5 x/
	3	11.6 x/
	4	6.4
14	1	-
	2	21.9
	3	11.4
	4	6.2
17	1	-
	2	20.7
	3	10.8
	4	5.8
20	1	-
	2	19.5
	3	10.1
	4	5.5

x/ The maxima where the average annual growth culminates

Heinsdijk and Glerum suggested that in order to maintain a reasonable annual outturn of Parana Pine, it would be necessary to restrict cutting to trees, 27.56 in. (70 cm) diameter at breast height and over.

2.612 In Other Countries

In areas outside its natural habitat there are variable reports of its growth and yield. In Queensland, Australia, a trial plot of 99 trees on a red-soil at Yarraman showed better growth than the adjacent crop of A. cunninghamii planted at the same time (Streets 1962). Four years after planting the mean height of plants raised from large seeds was 10' (3 m) compared with 7.5' (2.3 m) of the native species of the same age. The indications in Queensland appear to be that A. angustifolia grows faster in the early stages than A. cunninghamii and was reported to be of better form though less drought resistant.

The best examples of growth in Kenya are said to be in the East Rift zone where the rainfall per annum is 50" (1270 mm), divided between two rainy seasons. A sample plot at Uplands has shown a mean height of 93' (28.4 m) at the age of 42 years though the periodic mean annual increment had fallen off considerably (Wormald, op. cit). Diameter growth is reported to be slow in comparison to other conifers such as Cypress and Pinus patula 14.9" (37.5 cm) diameter at breast height standing at 140 stems per acre (346 stems per hectare) at age 36 years.

At Mtao in Rhodesia a plot of 33 year-old Parana Pine had a mean diameter of 16 in. (40.64 cm) over bark and heights ranged from 31-63' (9.45m - 19.2m). Another plot at Stapleford 27 years old had a mean diameter of 9" (22.9 cm) with heights ranging from 14' - 66' (4.3 - 20.1 m) and a mean annual increment of 24 cu. ft. per acre (1.7 m^3 per hectare).

In South Africa although results of the growth rate vary, the best results have been reported at Entabeni where a mean height of 73 ft. (22.3m) and diameter of 15" (38.1 cm) have been attained at 31 years, with a stocking of 126 stems/acre (311.2 stems per hectare) on a deep loam with 75" (1905 mm) of rain per annum and only light frosts at an altitude of 4500' (1372m) a.s.l. with a southerly to westerly aspect (Streets op. cit).

2.7 Protection

2.71 Insect Pests

Laspeyresia araucariae, a "seed moth", is known to attack the seeds in Brazil. But damage can be controlled by dusting recently collected seeds with 20 percent B.H.C. 10-17 ozs. per 220 lb. of seed (300-500 g/100 kg.)and storing it in a hermetically sealed container or plastic bags(Gaytontin,1960). Phrasterothrips conducens attacks the base of the leaves in the terminal shoot of the whorls, but new terminal shoots are formed thus preserving the whorl intact (Vernalha et al., 1964). Kuschel (1966) has reported and described two species of weevils belonging to the genus Araucarius (Cossoninae). These species are Araucarius ruehmi and A. brasiliensis and are said to be host-specific on A. angustifolia. In their attack the female and the male penetrate together through the periderm of the stem into the phloem where the female lays eggs either free in the lumen or in the sides of the breeding galleries. However, the two species do not attack healthy live tissues, i.e. they are secondary in their attack.

2.72 Fungi

A fungus,known as Uleiella paradoxa, parasitizes and greatly modifies the male strobili of Parana Pine (Barth 1964). In Kenya Phomopsis araucariae has been isolated from sickly trees and it was thought that P. araucariae may have been the causal agent. Also from Kenya, butt rot has been reported on 42 year old trees. The rot was said to have the appearance of Armillaria mellea infection. The incidence was only 25 percent. It might be higher in areas carrying indigenous hardwood (which were cleared and planted with A. angustifolia) than in areas which A. angustifolia has been planted more recently. The implication is therefore to avoid sites on which hardwoods have been recently cleared, especially sites carrying Parinari spp.

2.73 Animals

Horses and mules damage the bark of saplings (see 2.35 and 3.74).

2.74 Other Injuries

Parana Pine seedlings suffer from sun scorch unless they are properly protected. It is reported from Kenya that trees of all ages tend to lose their tops, also bark splitting of both branches and main stems has been reported - the splits being up to 12" (30.48 cm) long and 1" (2.54 cm) wide on 3" (7.62 cm) diameter stems. This bark splitting was, however, thought to be related to the excessive rain in the year 1961-62 (Wormald op. cit).

3.0 ARAUCARIA CUNNINGHAMII SWEET

3.01 Local Names

Colonial Pine, Hoop Pine, Richmond River Pine and White Pine.

3.02 Trade Name

Hoop Pine.

3.1 Distribution (See Map)

Hoop Pine has a wide altitudinal and latitudinal range. It is found naturally in Papua, New Guinea and in Australia. In the former it is found from sea level to approximately 8000' (2438m) above sea level (White and Cameron, 1965) and there are still extensive Hoop Pine areas in the Bulolo/Wau Valley in New Guinea. In Australia Hoop Pine is found from sea level to 3000' (914m) (Streets op. cit) and its commercial range extends from the Dorrigo plateau in Northern New South Wales to the neighbourhood of Rockhampton, Queensland; in addition it is found in a few limited areas on the Tully and Atherton tablelands of North Queensland.

Latitudinally Hoop Pine extends from about 30^{o} South in New South Wales northwards along the coastal range to tropical Queensland and across to the Arfak Mountains in New Guinea and the islands to the east of Papua to a latitude of 8^{o}S. (See map.)

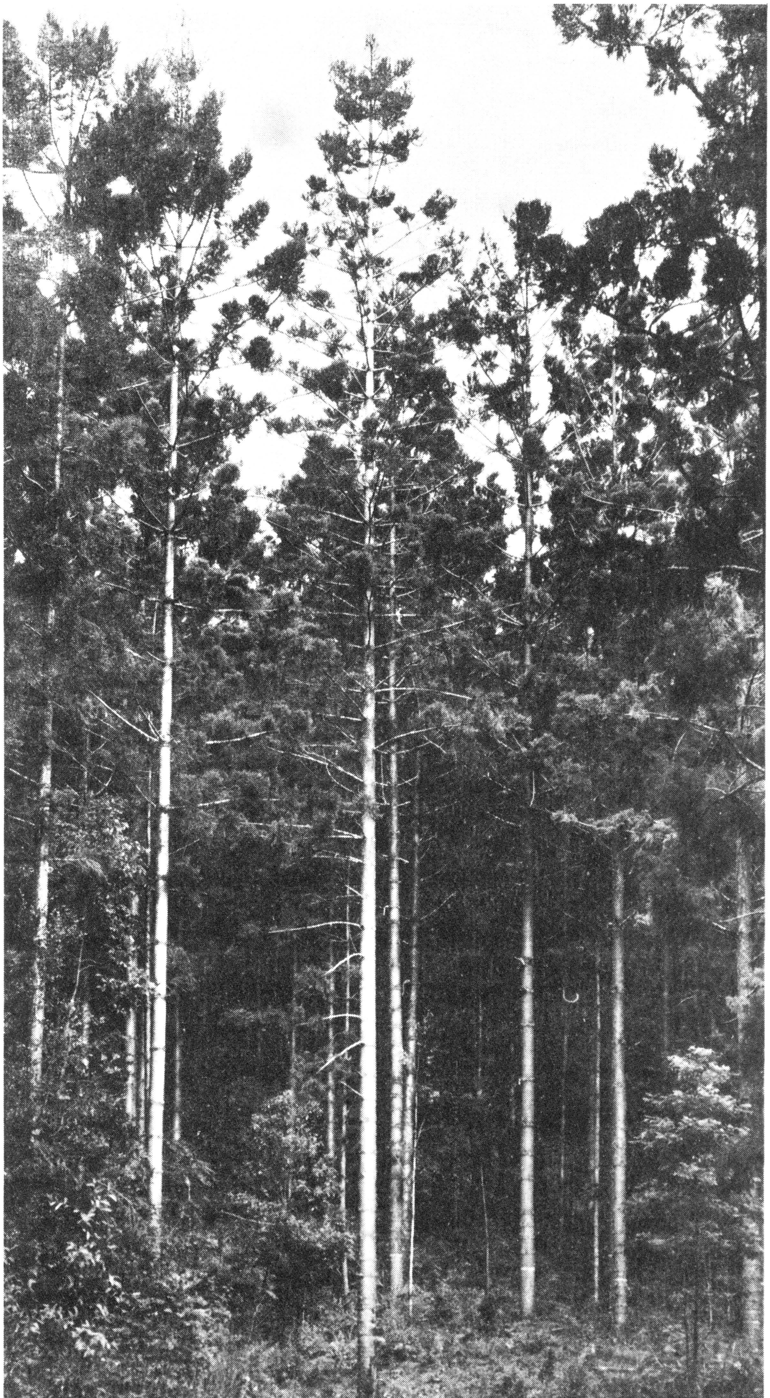
3.2 The Tree

3.21 In Australia

The tree grows very large and generally attains heights of 100'-150' (30.5-45.7m) and diameters of 2'-4' (0.61-1.22m), but dimensions of 200' (61.0m) in height and 5'-6' (1.52-1.83m) in diameter have been recorded (Anon, 1957).

Trunk: In the mature tree the trunk is free from branches, straight, with very little taper and often up to two-thirds of the total height. The main stem of the tree is persistent to the top of the crown.

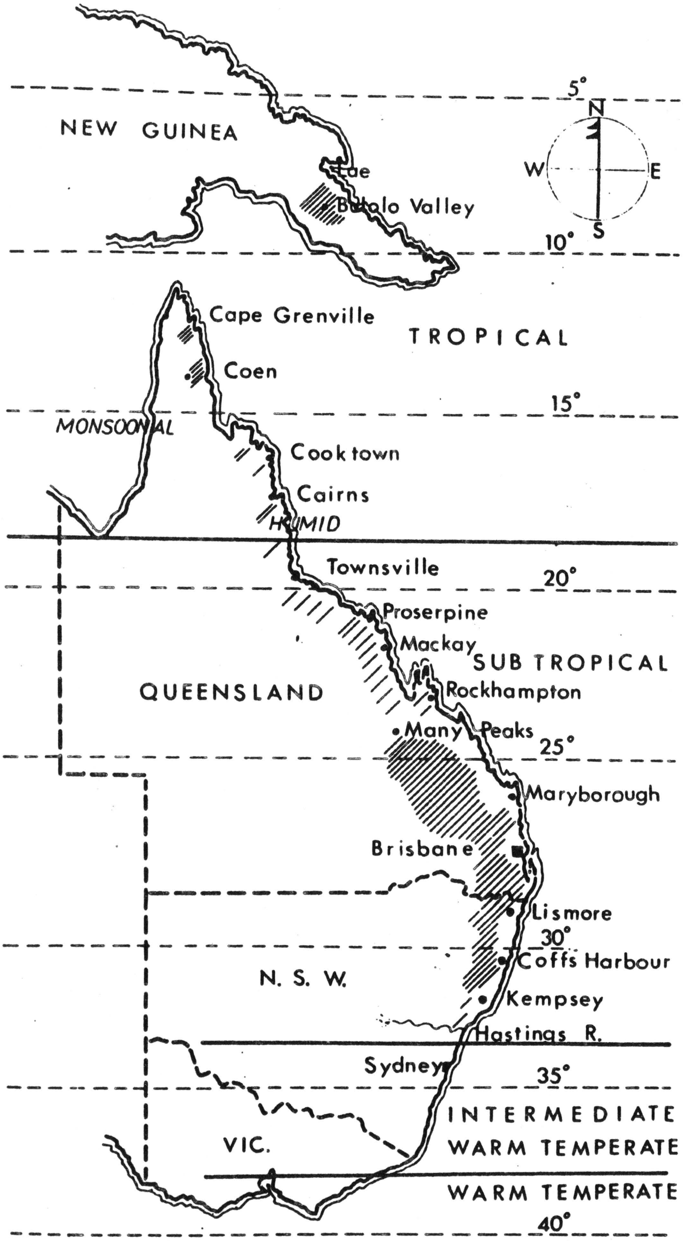
Bark: The bark is persistent over the whole of the trunk, to the small branches. It is hard and rough, with horizontal cracks forming circular hoops or bands and rectangular strips. The bark is thick, very dark brown or black on the surface and red when cut.



Araucaria cunninghamii Sweet

34 year-old plantation in Imbil State Forest, South East Queensland, Australia.

Photo : Department of Forestry,
Brisbane, Queensland.



Geographical distribution of Hoop Pine. Density of hatching approximately reflects abundance of the Araucarian forest type. The climatic regions are correlated with the distribution of the major structural forms of rain forest vegetation.

Reproduced by permission of Webb and Tracey (1967)

Crown: This is described as being less symmetrical than is usual in the genus.

3.22 In New Guinea:

Dadswell and Eckersley (1943) have described the Papua and New Guinea Hoop Pine as follows:

Height:	Up to 150' (45.7m)
Girth:	16' (4.88m)
Bole:	Up to 80' (24.38m) free of branches
Bark:	0.75" - 1" (1.9cm - 2.54 cm) thick, dark brown, very scaly and peels off in thick papery layers horizontally, giving the stem a ringed appearance and often the half-shed bark hangs raggedly to the stem
Crown:	About two-thirds of its total length it develops a crown of almost spearheaded outline, composed of open storied whorls of horizontal to ascending stick-like limbs, fringed and tufted with dark dull green foliage

While the above descriptions may not bring out any significant morphological difference between the Australian strain and the New Guinea strain of Hoop Pine, the indications are that they are different in form and manner of development. For instance, in Sabah, Nicholson (1964) has observed differences in form of two Hoop Pine provenances, one from Queensland and the other from New Guinea (both planted in 1960). He found that the two provenances were distinct in form and had developed differently. The New Guinea strain had from the beginning looked healthier and robust and had no longer the first and second order branches at the time that Nicholson made his observations. Further it was observed that the second order branches were more pectinate in their arrangement and had a lesser tendency to branch again and were closer together (2 per inch as against 1.6 for the Queensland strain). Nicholson pointed out that differences in growth rates and form between these two provenances had been noted in Queensland where the local strain was behaving better, with less taper and better height growth than the New Guinea strain; also the Queensland strain carried lighter crown and suffered less set-back in pruning.

3.3 Habitat Conditions

3.31 Climate

3.311 Rainfall

Hoop Pine is naturally suited to areas with summer rainfall and dry winters. But it has limited prospects of growing in areas where the rainfall is uniformly distributed throughout the year and no dry season (Golfari, op. cit). Rainfall requirements range from 40" to 60" (1,016 to 1,524 mm) per annum with most of it falling during the summer months, January to April in Australia.

3.312 Temperature

In Southeast Queensland where the species is commonest the climate is sub-tropical with warm humid summers and mild winters. Near the sea there are no frosts, but inland at higher elevations there may be up to 20 frosty days a year (Anon, 1957). Mean annual temperature varies between 21.1°C to 26.6°C (70°F to 80°F) and that of the coldest month is between 9.4°C and 17.7°C (49°F and 64°F). For the climatic data on Hoop Pine see para 2.312.

3.313 Frost

Extreme cold has an injurious effect on Hoop Pine seedlings - drooping of branchlets and flopping over of the leader. Cromer (1940) summarised the effect of extreme cold on tubed stock as follows:

(a) Young plants are less susceptible than old ones
(b) Small plants are less susceptible than large ones
(c) No damage results from temperatures of 23°F (-5°C)
(d) The critical temperature of two-year-old stock is 19°F (-7.2°C)

With Hoop Pine care must be taken to select sites free from heavy and late frosts. This has led in New South Wales to the restriction of planting sites to sub-tropical and dry rainforest areas below 200' (61.0m) elevation (Baur, 1962).

3.32 Edaphic Factors

Hoop Pine grows on a large variety of soils, provided that they are well-drained and kept moist all the year round. It particularly favours soils derived from metamorphic rocks, basalt and granite and for best development requires deep, moist, fertile, clayey loam.

3.33 Physiographic (topography) Factors

In Australia Hoop Pine is mainly a species of the coastal ranges and the topography upon which it occurs varies from undulating to mountainous (Anon, 1957); also in New Guinea it ranges from sea level to elevations of 8000' (2438m) and extensive areas remain in the Bulolo/Wau valley.

3.34 Ecological Associations

Anon (1957), Webb (1959), Baur (1962) and Webb & Tracey (1967) are among the recent studies which have been made on the ecological associations and seral status of Hoop Pine. Their views are summarized as follows:

A. cunninghamii rarely forms a pure stand under natural conditions. It occupies different seral status in different forest types, for example in Queensland it occurs as an emergent tree above a canopy of broad-leaved vine forests which range from wet complex or simple notophyll to moist microphyll vine woodland and dry semi-evergreen vine thicket (Webb and Tracey, 1967). Hoop Pine is not a climax species of the rainforest type because it cannot regenerate under the shade of climax rainforest species. In the wet sub-tropical region it occurs as part of the climax forest only in soils of relatively low fertility. In soils of high fertility in the wetter areas Hoop Pine is replaced by its broad-leaved competitors and here it does not occur in the climax forest except as a rare veteran tree and its regeneration is restricted to earlier stages of succession following drastic disturbance of the canopy and the soil humus layers by cyclones, fire, litter removal or clearance by man. It is therefore a secondary species of the rainforest type which invades rainforest sites after the canopy and the forest floor have been disturbed.

In these subtropical rainforests Hoop Pine is associated with such species as Tarrietia spp., Sloanea woollsii, Dysoxylon, Alaeocarpus, Ficus, Eugenia, Cryptocaria, Listea and Cinnamomum spp. Being a light demander it may eventually be ousted by these hardwoods unless a second opening in the canopy occurs. Although Hoop Pine is a light demander it does not regenerate under full light caused by the removal of trees. Hoop Pine also occurs in the dry rainforest where the seasonal rainfall regime is down to 40" (1016mm) per annum in parts of the Richmond-Tweed centre of New South Wales (Baur, 1962). In this forest type Hoop Pine is associated with such species as Siphonodon australe, Planchonella pohlmaniana and several Flindersia spp. Where Hoop Pine extends to soils of high fertility in these drier subtropical regions it regenerates within the climax forests. Also in dry situations such as steep stony slopes of the wetter coastal ranges Hoop Pine again enters the climax vine forest.

In many parts of its range, Hoop Pine must be regarded as being characteristic of forest types intermediate in ecological succession between rainforest and hardwood forest (Anon, 1957). The term 'hardwood forest' (as it is understood in Australia) is used to describe a forest type dominated by Eucalyptus spp. and characterised by burning of the undergrowth. Its nearest equivalent in Africa is the Miombo type woodland.

In New Guinea the Araucaria forest is usually restricted to sloping and steep topography. Hoop Pine occurs with Klinki Pine with one or the other species predominating. Hoop Pine is widespread throughout New Guinea between 500' and 5000' (152.4 - 1524m) above sea-level, but Klinkii Pine is much more restricted in distribution (Womersley, 1958). Further information on the association of Hoop and Klinkii Pines with other species in New Guinea will be found in para 4.34.

3.35 Mycorrhizal Association

It is known that some mycorrhizae are in association with the roots of Hoop Pine. One of these is endotrophic in form. Young (1940) reported that in a pure culture experiment, Hoop Pine seedlings have produced mycorrhizae when grown in association with a fungus called Boletus granulatus, and also with an undetermined fungus isolated from naturally occuring Hoop Pine mycorrhiza. Young further observed that Hoop Pine seedlings failed to develop in pure culture without the presence of a mycorrhizal fungus.

Griffiths (1965) has also observed the presence of an endotrophic mycorrhiza in both Hoop and Klinkii Pines. In each species the intracellular mycorrhizal fungus was found to be septate and the mycorrhizal roots were short and thick, pink-red in colour and similar to the parent root. The mycorrhizae were found to be confined to the cortical region although the infection extended from the piliferous layer to the endodermal/pericyclic layers. Singh and Kumal (1966) in a field survey of mycorrhizae in Eucalypts and Pine nurseries in Southern India have reported that Eucalyptus grandis and E. tereticornis raised in the nurseries developed mycorrhiza. Hoop Pine grows well in these nurseries but seldom develops mycorrhiza.

3.36 Effect of Fire

Hoop Pine is extremely fire sensitive.

3.4 Life History and Development

3.41 Flowering

While the flowering habits of Hoop Pine are still being investigated, Nikles (1962) has drawn attention to the following points:-

(a) Flowering normally occurs in December and January in Queensland
(b) Several trees have been noted in which flowering was consistently late, even as late as May
(c) The flowering period is more than a month and this is much longer than most conifers
(d) The normal condition appears to be synacmous flowering (i.e. stamen and pistil maturing simultaneously), though phenological barriers (for example, stamen and pistil maturing at different times) which prevent selfing are present in most trees
(e) Cross-pollination appears to be the rule

3.42 Seeding Age and Seed Production

Lahiri (1947) has reported favourably on the performance of Hoop Pine in Mauritius, where trees grown at an elevation of 200' to 1000' (61 to 305m) with a fairly distributed rainfall of 50"-60" (1270-1524 mm) per annum have started to produce fertile seeds at the age of 15 years. Grenning (1957) has stated that under plantation conditions in Queensland Hoop Pine does not produce any appreciable quantity of fertile seeds until over 20 years of age. Parana Pine has been reported to produce flowers and seeds at the age of 15 years in Kenya. The indications are that under favourable conditions Hoop Pine would flower and seed between the age of 15 and 25 years. Usually the male flowers appear at base of crown in young trees and the female at the top. As the tree grows older the male and female flowers come nearer and nearer to each other.

3.43 Seed Quality, Storage and Germination

The quality of seeds collected at the correct time is fairly high. Hoop Pine seed does not ordinarily keep for more than a year before it begins to deteriorate and lose viability. At best the seed is viable until the spring following the summer of its dispersal, after that viability falls rapidly unless put in cold storage. It is best stored under refrigeration in tightly packed containers and never kept at room temperatures. It should be stored at a temperature of $10^{o}F$ ($-12^{o}C$) preferably in copra sacks as in New Guinea, to prolong its viability. In Queensland, seeds cold-stored at $35^{o}F$-$40^{o}F$ ($1.6^{o}C$-$7.2^{o}C$) will retain viability for up to six years (Hawkins and Muir, 1968).

Under suitable conditions germination may commence from four to ten days after sowing (Swain, 1924). In Queensland germination may take place in almost any month of the year, but takes longer as the weather gets cooler. In warm situations Hoop Pine seed will germinate in midwinter in 30 days and in cool situations the seed may remain in the seed-beds throughout autumn and winter and there are reports of seeds germinating 281 days after sowing (Swain, op. cit).

3.44 Dissemination of Seed

Hoop Pine seed is disseminated by wind as well as by the falling of the complete cones to the ground. Seeds may be carried a few chains away by wind if the mother-tree stands in the open or at the edge of plantations, but where the canopy is fairly dense the seeds are intercepted by tree tops.

3.45 Seedling

The nature of the taproot system of Hoop Pine has been outlined in para 2.523, but the following additional points should also be noted. Hoop Pine seedlings develop long and strong tap-roots to enable them to reach the subsoil. This long and strong tap-root makes transplanting operations very delicate and that is why root-wrenching is a necessary nursery operation. However, the seedlings are hardy, can withstand drought in some situations and are frost-resistant. The seedlings are damaged or killed outright by insolation, prolonged drought and late frosts, particularly in exposed situations.

3.5 Silviculture

3.51 Natural Regeneration

In Australia and New Guinea attempts to regenerate Hoop Pine naturally were not successful. It was pointed out in para 3.34 that Hoop Pine is not a climax species and does not regenerate under shade. Several methods were tried, but it was found that those natural seedlings which survived under the forest canopy soon died when the canopy was removed mainly from insolation and drought because of the letting in of the full blaze of the sun, and from browsing by wallabies and chewing by grasshoppers. It was therefore decided that it was not economically practicable to regenerate Hoop Pine naturally.

3.52 Artifical Regeneration

The standard and most successful method of regenerating Hoop Pine both in Australia and New Guinea is by artifical planting. This is borne out by the extensive areas of established plantations of this species in both countries and has been achieved in spite of initial difficulties; in fact Hoop Pine has now proved easy to handle both in the nursery and in plantation establishment. The techniques used in the nurseries and in the plantation establishment for Hoop Pine in Queensland and New Guinea are essentially the same although in New Guinea there are slight modifications, in some areas, mainly in the timing of silvicultural operations. Otherwise the following account applies to both countries; where there is obvious difference this will be emphasised.

3.521 Seed
(See also para 1.242)

Hoop Pine seed is woody, kite-shaped and weighs about 1200 seeds to the lb. (2667 per kg), (Swain, 1924). But Hawkins and Muir (op. cit) have recorded an average of 2000 seeds to the lb. (4444 per kg). The mature seed is golden brown in colour. Hoop Pine seeds every year, but heavy seed fall occurs only in every three to four years during which large quantities of fertile seeds may be obtained.

3.5211 Seed Trees
(See also para 4.5211)

In Queensland the selection of seed trees is done prior to commencement of collection and such trees are marked not later than the first week in December so that if seed should ripen abnormally early collection might commence with a minimum of delay. Selection of trees is confined to those 48" + g.b.h. (121.92 cm +) within scrub areas and on scrub edges to trees 24" + g.b.h. (60.96 cm +).

3.5212 Seed Collection

Collection of cones should begin when the first trace of brownness is observed on the cone. In Queensland collections are not made from planted areas unless there has been a heavy production of pollen two years earlier and it is usual to observe pollen production between 1st January and 31st March on all plantation areas over 20 years of age. Cones are collected from the final crop only and cones which have fallen to the ground are not collected except those dislodged from the tree in the process of felling the tree.

Cone collection should be correctly timed because experience has shown that cones collected at the peak of the season contain the highest proportion of mature and fertile seeds. For example, observations in New Guinea show that the majority of Hoop Pine cones enter their main stage of development late in their second year and complete it by September. Also the maturing of individual cones is influenced by location, altitude, aspect and by weather conditions. For instance the probable maturing periods in New Guinea are:

Location	Altitude	Matureness
Mai Ama	300' (91.4 m)	Late September
Bulolo-Wau	3 - 4000' (914-1219 m)	Late Sept. /early Oct.
Okapa	3 - 4000' (914-1219 m)	Late September
Woitape	5 - 6000' (1524-1829 m)	Late Oct. /early Nov.

In New Guinea prior to collection an estimate is made in late July or early August of the crop potential in each collecting area. This estimate is based on the counts of cones on trees selected as representative of the stand. The count is made by climbing and harvesting the cones. The yield of dry fertile seed from green cones is known to be approximately 36 percent and a working ratio of 3 lbs (1.36 kg) of green cones to 1 lb (0.45 kg) of dry seed is used. On the basis of crop potential and access Hoop Pine stands are selected and cone samples taken every week from 1st August onwards. This sample consists of two to four trees from each selected stand.

Only second year cones are collected. In New Guinea it has been found that the most efficient and practical method for timing Hoop Pine matureness is to measure the time taken by cones to disintegrate, because ripe cones spontaneously disintegrate within seven days, releasing a rich, golden brown seed which when cut open shows a well developed embryo with the four cotyledons easily distinguishable (seeds may be boiled for five minutes to assist dissection). A quick guide to matureness is to cut open the cone and determine the hardness of the seedscale. If the seedscale can be split open, or if the quarter inch of the seed next to the columella (central column of the cone) is still soft and can be broken off, then the seed is immature. On ripe seeds the scale is quite hard and difficult to split (White and Cameron, op. cit).

Collected cones are spread on shelves in single layers for drying and should be turned daily. The cones should commence to disintegrate within a few days. In New Guinea when the cones begin to disintegrate the end quarter of the central stock is discarded and the seed scales from the central section are spread over the shelves. Cones which fail to disintegrate within ten days are discarded, being considered too immature.

3.5213 Treatment of Seeds

If insect attack is noted during the drying period an appropriate insecticide should be applied. For example in New Guinea the cones are dusted with gammexane. Seeds should be packed in suitable containers and labelled, giving such particulars as seed batch number and weight of seed in the container.

3.522 Direct Sowing

Direct sowing of Hoop Pine is not a common practice and it is not recommended. All seedlings are usually raised in the nursery, the details of which are given below.

3.523 Nursery Practice

3.5231 Bed Preparation
(See Klinkii Pine)

Seed beds should normally be dug to spade depth and the soil thoroughly turned over. It is the practice in Queensland, Australia, to allow the beds to lie in the rough for at least one week and then to dig them over again. All clods are broken and the beds worked up to a fine tilth, removing all weeds in the process. Where manures are to be applied they should be added at this time and worked to the top 4" (10.2 cm) of the bed. The application of manure should be done early enough to allow the germination and removal of the resulting weed before the seed is sown. The day before sowing the surface of the bed should be loosened, carefully levelled and then given a light watering.

3.5232 Sowing Season

In Queensland Hoop Pine seeds are sown in the spring before the end of October. The rate of growth is also very important. Again in Queensland where the rate of growth varies not only from district to district but also from nursery to nursery within a district the season of sowing has to be varied to suit the rate of growth secured in a particular nursery. Rate of growth also determines the time which must elapse between sowing and the despatch of stock to the field.

In New Guinea Hoop Pine seeds are sown in October-November.

Method of Sowing and Treatment of Seed

This is the same as for Klinkii Pine, i.e. sow broadcast. (See para 4.5243). In Australia drill sowing is also a standard practice. Seeds should be treated with an appropriate fungicide to prevent damping-off. For example, in Queensland, unstratified seeds are treated with Captan 50 at the rate of 18 oz. (510.3 gm) per 100 lb. (45.4 kg) of seed.

Type of Cover

Depth of cover is the same as for Klinkii Pine (See 4.5243). Care should be taken to ensure that seeds are not piled one on top of the other. This applies particularly to drill sowing and it is suggested that flat bottomed drills should be obtained by using 1" x 3/4" (2.54 x 1.9 cm) battens nailed at 8 in. (20.3 cm) centres to the under surface of a 12 in. (30.5 cm) plank. The use of such planks gives two drills 1 in. (2.54 cm) wide, 3/4" (1.9 cm) deep and 8 in. (20.3 cm) apart.

Density of Sowing

In high shade nurseries the sowing density aims at a stocking of 8 plants per foot of drill in drills 8 in. (20.3 cm) apart or 12 plants per square foot of bed. In low shade nurseries sowing aims at producing a crop of 3000 seedlings per 48 ft. x 4 ft. (14.63 x 1.22 m) bed. The above sowing densities apply both to New Guinea and Queensland.

3.5233 Shading
(See 2.5231 for construction of high shade supports)

In Queensland no shade is provided in low shade nurseries, for one week after sowing, but from the end of the first week to the middle of March in the year of tubing 50% shade is provided; from the middle of March to the end of April this shade is gradually opened out and by the end of April the shade is completely removed. Where nurseries are subject to early frosts 50% shade remains throughout the risk period.

In New Guinea newly sown beds of Hoop Pine are given shade within one week of sowing, using slats spaced 1" (2.54 cm) apart. This shade is gradually removed after two months until full light is admitted by the following November. In other words, full light is not admitted until nearly one year after sowing. In this respect the shade and/or light requirement of Hoop and Klinkii Pines is significantly different (see 4.5244). Plastic netting is now replacing slats as overhead shade (see 2. 5231).

3. 5234 Watering and Weeding
(See 2. 5233 and 4. 5244)

3. 5235 Cultivation

Drill sown stock should be cultivated after the germination is complete. In Australia it is usual to cultivate at four-weekly intervals until the end of March following sowing, i. e. for about five months.

Thinning

Thinning to 8 plants per linear foot of drill is the routine practice in Queensland. Pegg (1965) has found that while heavier thinning to, say, 5 plants per foot gave a higher percentage of 7"+ 17. 8 cm+) plants for tubing and fewer spindly plants, the routine thinning to 8 plants per foot gave results close to the desired 3000 tubed plants from a 48' x 10' (14. 63 x 3 m) bed. He suggested that there was no reason for carrying out a heavier thinning schedule for Hoop Pine seed beds, but that attention should be given to the thinning of all clumps to the correct spacing, irrespective of gaps in the bed.

In New Guinea thinning is carried out after four months and the beds are thinned to leave 12 plants per square foot, i. e. 2400 per bed.

3. 5236 Root Wrenching (Pruning)
(See 2. 5234)

3. 5237 Lifting
(See 4. 5247)

3. 5238 Grading

Stocks for tubing should be graded according to size. In New Guinea stocks are graded as follows:

a/ Plants 7 - 10" (17. 78 - 25. 4 cm) in height
b/ Plants 10 - 14" (25. 4 -35. 56 cm) in height
c/ Plants 14 - 20" (35. 56 - 50. 8 cm) in height

But in Queensland, Australia, there is a fourth grade, 19 - 24" (48. 26 - 60. 96 cm) of tubing stock. Height refers to the distance between ground level and the growing tip. Plants below and above this height are discarded. The importance of size and age on the survival of seedlings after transplanting is discussed in para 4. 5248.

3.5239 Tubing
(Fuller details are given in para 4.5247)

Every effort should be made to locate ample supplies of black or dark grey soil containing sufficient plant foods. Such soil should bind well, should not be sticky when moist and should leave the tube easily at planting. Soils containing gritty and abrasive materials should be avoided.

Season of Tubing

This would be dependent on the time when planting is to be commenced and completed. Usually tubed stock must remain in the tube for a period of from 10 to 13 weeks before being planted into the field. During this period a satisfactory root development and compaction of the core must have been achieved. For example in Queensland, Australia, where planting is to be completed before Christmas tubing is completed by mid-September or at the latest by the end of September. Tubing therefore does not commence before 1st July.

The season of tubing in New Guinea is when the majority (75 percent) of the stock is 6"-9" (15.24 - 22.86 cm). For instance when the season of sowing is October-November suitable stock nine months old should be produced by July-August the following year. Tubing should be done in dull, rainy weather.

3.524 Plantation Establishment

The method of establishing plantations of the three species of Araucaria is essentially the same. Reference should therefore be made to what has been said about A. angustifolia. But it should be noted that local conditions would make modifications necessary. The following points should be noted in respect of A. cunninghamii:-

3.5241 Site Selection and Preparation

In Australia, for example, plantations of Hoop Pine are confined to areas carrying the following vegetation types:-

1. True rainforest carrying Hoop Pine
2. Continuous development of rainforest 60' (18.29 m) + in height
3. Areas with a strong development of scrubby underwood containing true rainforest species

It is therefore important to select areas within a rainforest vegetation type. Closed forest on sites should be clear felled and burnt a short time before the rainy season begins. Such sites are not usually stumped or ploughed. On grassland sites ploughing is possible on reasonable slopes and improves early growth by reducing grass competition.

3.5242 Size of Plants

The importance of size of planting stock is discussed in para 4.5248. In Australia the minimum size of planting stock is 7" (17.78 cm) and the maximum is 24" (60.96 cm) for Hoop Pine. In New Guinea the minimum size is 9" (22.86 cm) and the maximum is again 24" (60.96 cm). Sturdy 15" (38.1 cm) tall plants with well balanced crowns are the most desirable. Again in New Guinea large sturdy stock 18"-24" (45.72-60.96 cm) are usually selected for grassy areas.

3.5243 Planting
(See A. hunsteinii, para 4.5253)

3.5244 Tending

Tending in the first four years is important. Again no rule or schedule of tending is to be laid down here as the intensity of tending would depend on local conditions of weed and other noxious growth. It is essential that plantations should be kept free of weeds during the first four years of slow height growth and until the trees have closed canopy. It is also important that tending methods are compatible with low cost. Tending costs in Queensland are reduced in some areas by permitting grazing in 3-4 year old compartments. The prickly leaves of Hoop Pine protect it against the damage from grazing animals. This is usually the heaviest item in the cost of raising Hoop Pine plantations.

3.5245 The Effect of Cultivation and Fertilizers on the Establishment of Hoop Pine on Poor Sites

Richards (1967) has made a study of the possibilities of establishing Hoop Pine on lateritic podsolic soils (such as those found in the coastal lowlands of Southern Queensland, Australia) which are unsuitable for Hoop Pine. Richards investigated (a) The effect of site preparation and found that differential site preparation markedly affected the development of the trees and that early growth of Hoop Pine was greatly stimulated by the removal of blady grass (Imperata cylindrica). Cultivation increased height growth by 194%. The beneficial effect of pre-planting cultivation was closely related to the destruction of blady grass which competed with the Araucaria both for water and nitrogen. It was found that early growth of Hoop Pine could be achieved by cultivation of the site to reduce competition with grass or other herbaceous weeds. But the effect of cultivation was found to be ephemeral and unlikely to persist long enough to permit the trees to gain control of the sites, unless nitrogen fertilizers were added as well. (b) Effect of added nutrients. The addition of sodium nitrate (Na NO_3) and sodium sulphate (Na_2SO_4) increased height growth, but no other salt was found to have a significant effect on height growth. Chemical analysis of Hoop Pine at the age of 4½ years showed that the concentrations of Nitrogen, Phosphorus, Potassium and Sulphur (N. P. K. and S.) in the foliage were all increased by the addition of salts which contained these elements. But only in the case of nitrogen was nutrient concentration correlated with mean height or height increment. Richards found that sodium phosphate (NaH_2PO_4) and ammonium sulphate ($(NH_4)_2SO_4$) increased height growth by 109% and 192% respectively. Urea and lime both increased height growth, the increase in mean height at about 5 years of age, being 246% from the application of urea and 111% from the application of lime. (c) Limiting nutrients. The major limiting nutrient was found to be nitrogen and large responses were obtained to all three forms of nitrogen applied, namely sodium nitrate, ammonium sulphate and urea. It was found that virtually no growth occurred, except on cultivated sites, unless nitrogen fertilizers were added. The response of Hoop Pine to phosphorus was slight.

The foregoing indicates that rapid establishment of Hoop Pine on poor soils could be achieved by combination of pre-planting cultivation and the application of nitrogen fertilizers. In conclusion Richards expressed the view that a rain forest species such as Hoop Pine could be grown in a dry sclerophyll forest environment (such as the vegetation which dominates the coastal lowlands of Queensland, Australia) with the aid of added nitrogen fertilizers.

3.5246 Underplanting

This method of growing Hoop Pine has been attempted in Australia with variable results. Investigations in the coastal lowland of Southern Queensland (where the soil consists chiefly of infertile lateritic podsol and therefore unsuited to Hoop Pine) have shown that Hoop Pine can be successfully established on any site, which is already carrying a healthy stand of Loblolly Pine (Pinus taeda) and Slash Pine (Pinus elliottii) at least five years old (Richards, 1961). While the mechanism involved in the underplanting effect is still being studied it has been suggested that the critical factor is essentially one of nitrogen supply and demand and Richards has expressed the view that Hoop Pine is unable to satisfy its nitrogen requirements when planted on coastal lowlands carrying scrub, but is able to do so when underplanted to Pinus. The promise of improving the productivity of Slash Pine plantations by underplanting is indicated by recent data from the oldest Hoop Pine underplanting in Queensland, Australia.

Growth of Hoop Pine underwood and Slash Pine overwood (Site Index 81*)

Species	Age	Stems	Mean g.b.h.o.b.	Basal Area		Predominant** height
				Standing	C.A.I.	
	yrs.	acre (ha.)	ins. (cm)	sq.ft. (sq.m)	ft. (m)	ft. (m)
Slash	30	122 (301)	41.5 (105.4)	119.2 (11.07)	4.9 (1.49)	86.5 (26.4)
Hoop	15	210 (519)	15.6 (39.4)	29.2 (2.71)	3.2 (0.97)	50.6 (15.4)
Total		332 (820)		148.4 (13.78)	8.1 (2.46)	

* Site Index is actual or anticipated predominant height at age 25 years.

** Predominant height is the mean of the heights of the tallest tree on each twentieth acre.

Source: (From 1966-67 Annual Report,Dept.of Forestry, Queensland, Australia.)

3.5247 Pruning

The objectives of pruning Hoop Pine are given under A. hunsteinii in para 4.528).

The following pruning prescriptions have been laid down for Hoop Pine in Queensland, Australia:-

3.52471 First Pruning

(a) The initial selection is made when 75 percent or more of the stems in the stand exceed 17' (5.18 m) in height. There are different prescriptions for different localities. For example, in the Yarraman, Murgon and Monto areas the first initial selection is made where 10 percent or more of the stems in the stands exceed 20' (6.1 m). This figure increases to 22' (6.71 m) in height for plantations in the Gympie Mary Valley and North Queensland areas.

(b) The basis of selection is to prune only reasonably well formed trees in a stand where 10-75% of the stems exceed 22' (6.71 m) in height.

(c) Where 75 percent of the stand exceed 20' (6.1 m) or 22' (6.71 m) in height, selection and pruning are completed in one operation and this selection for a complete first pruning aims at the selection of about 240 of the best stems per acre (593 per ha) and the allowable range for such selection is from 230 to 260 stems per acre (568 to 642 per ha).

(d) In selecting the best 240 trees per acre (593 per ha) trees under 20' or 22' (6.1 or 6.71 m) in height are not selected, neither are the trees which are badly diseased and of poor form. Every tree of really good form is selected unless it is below 20' or 22' (6. 1 or 6. 71 m) in height or is badly formed and diseased. Only the best tree in every group of 4 trees in the plantation are selected for pruning and in considering groups of four, blanks are usually regarded as trees.

(e) First pruning is to be as high as can be reached from the ground.

3. 52472 <u>Subsequent Prunings</u>

In subsequent prunings two stands are distinguished in Queensland, namely

(a) where first pruning is completed in one year;
(b) where first pruning is spread over two years.

In (a) selection for subsequent pruning is delayed until the year following the complete initial pruning. Stems are selected on the basis of form, vigour and location, aiming at a spacing of about 19' x 19' (5. 79 x 5. 79 m). In the year of selection and in the following year, each select stem is to have 4' (1. 22 m) of the stem pruned (measured from the last pruned whorl) and in the second year after selection pruning should be completed to 21' (6. 40 m) and no whorl at or above 21' (6. 40 m) is to be pruned.

In case (b) two years are covered in the initial pruning and in consequence there will be in the stand trees pruned in the first and trees pruned in the second year. Immediately the first pruning is complete, the selection for subsequent pruning is made and pruning is carried out 4' (1. 22 m) only on those select stems which were pruned in the first year. In each subsequent year each select stem is to have 4' (1. 22 m) of the stem pruned until a minimum height of 21' (6. 40 m) is attained.

From the above account it is clear that pruning is carried out in stages and the objective is to have about 120 trees per acre (296 per ha) pruned at least 21' (6. 40 m) with a central knotty cone that does not exceed 6" (15. 24 cm) in diameter.

Pruning prescriptions for Hoop and Klinkii Pines are the same in New Guinea.

3. 5248 <u>Thinning</u>

3. 52481 In <u>Queensland</u>, Australia, elaborate thinning schedules for Hoop Pine have been developed. The prescriptions fall under three main headings, namely:

(a) Unmerchantable thinning (silvicultural/cleaning operation)
(b) Merchantable thinning in which the stands are not thinned unmerchantably (i.e. thinning to produce saleable material and to favour selected stems)
(c) Merchantable thinning in which the stands are unmerchantably thinned to 400 stems per acre (988 per ha.) (a further thinning to favour final crops)

Unmerchantable Thinning
(Silvicultural/cleaning operation)

Under this schedule Hoop Pine plantations are thinned unmerchantably when the stand planted at a spacing of 9' x 8' (2.74 x 2.44 m) averages 15' (4.57 m) in height. In this operation the marking for thinning is on a row by row basis in which all hopeless trees are removed and not more than two consecutive blanks are created. Efforts are made to avoid the enlargement of existing blanks. The stocking aimed at after this thinning is between 360 to 420 stems per acre (889 to 1037 per ha).

Merchantable Thinning
(in which stands are not thinned unmerchantably (i.e. thinning to produce saleable material and to favour selected stems.)

The main object of this thinning is to promote the growth of high quality wood and to concentrate that growth on the best stems which have been selected for pruning in the stand. Such a stand is ready for thinning when it will yield a merchantable volume u.b. to 4" (10.2 cm) d.u.b. of 3000 super.ft. (Hoppus), per acre in stems other than the select stems and over the minimum G.B.H., usually 18" G.B.O.B. (14.55 cm diameter).

Thinning intensity aims at a stocking of approximately 350 effective stems per acre (865 per ha) equivalent to a spacing of 11' x 11' (3.35 x 3.35 m). An effective system is defined as one which has a G.B.H.O.B. of 12" (9.7 cm diam.) plus in a stand whose predominant height ranges from 45' to 55' (13.72 m - 16.76 m).

The first merchantable thinning under this prescription aims at ensuring the dominance of the select stems and the reduction of the stand to approximately 350 effective stems per acre (865 per ha). In the second and subsequent thinning most weight is given to the removal of stems other than select, severely competing with the select stems, plus additional stems necessary to reduce the stocking to 250 effective stems per acre (618 per ha).

Merchantable Stands unmerchantably thinned to 400 stems per acre (988 per ha) - a further thinning to favour final crops

Stands are ready for this type of thinning as soon as possible after they have reached a basal area of 130 sq. ft. per acre (37.98 sq. m per ha).

Thinning intensity in the first thinning aims at a stocking not below 300 effective stems per acre (741 stems per ha), equivalent to a spacing of 12' x 12' (3.66 x 3.66 m) and to ensure the dominance of select stems. In the second and subsequent thinning most weight is given to the removal of stems competing with the select stems, plus additional stems necessary to reduce the stocking to 220 effective stems per acre (533 per ha).

3.52482 Papua and New Guinea

The foregoing is a summary of the thinning prescriptions for Hoop Pine in Queensland, Australia. New Guinea has adopted similar thinning prescriptions for New Guinea Hoop Pine, but the schedule is less elaborate than that of Queensland. The following schedule is in operation in New Guinea (White and Cameron, op. cit):

Hoop Pine Thinning Schedule

Age (years)	Stems/acre	Stems/ha	Removal in thinning		Remain	
			Per acre	Per ha	Per acre	Per ha
7.5	450	1112	150	(371)	300	(741)
12.5	300	741	120	(296)	180	(445)
17.5	180	445	60	(149)	120	(296)
22.5	120	297	40	(99)	80	(198)
27.5	80	198	25	(62)	55	(121)
35.0	55	136	15	(37)	40	(99)
40.0	40	99	40	(99)	-	-

The above schedule is simple and shows that thinning is at five-yearly intervals until the age of 27½ years. Under this schedule first thinning is applied at the time of high pruning and the type of stems marked for removal are the same as presented for Klinkii Pine; the thinning intensity is also the same (see para 4. 529).

3. 52483 Basal Area Control

It has been found that basal area is a better basis for control of Hoop Pine thinning experiments than an integration of stocking, age and site (Robinson, 1968). In New Guinea thinning schedules using basal area as the major production index are being investigated (Suttie, 1968), and for many years this has been under investigation in Hoop Pine plantations in Queensland, Australia.

Experiments at Yarraman and Imbil (Queensland) have indicated that the value of using basal area control is becoming increasingly significant. The advantages of these experiments are said to lie in the ease and definiteness of control and the fact that the results can be converted to the number of stems per acre (per ha). Evidence is also mounting that a strong relationship exists between standing basal area and basal area increment in Hoop Pine and other conifer plantations in Queensland.

An example of this experiment is that established in November 1951 on compartment 5, Rocky Logging Area, R. 289, Yarraman. This area was planted in December, 1936 and was unthinned at the time of commencement of the experiment. Thinnings were carried out in 1951, 1954, 1956 and 1958. The aim of each thinning was to thin so that the average basal area standing for the following two years would be close to the desired control and in this experiment the average basal areas arrived at were 160 sq. ft., 130 sq. ft., 110 sq. ft., 90 sq. ft. and 70 sq. ft. per acre (36. 74 m^2, 29. 85 m^2, 25. 16 m^2, 20. 66 m^2 and 16. 10 m^2 per ha). Results obtained are shown in the tables on page 44.

The table shows the average annual basal area increment for the period 1952-1958 (age 15½ - 21½ years). The maximum basal area increment is about 9 sq. ft. per acre (2. 1 m^2 per ha) and is associated with a standing basal area of 120-140 sq. ft. per acre (27. 55 m^2-32. 14 m^2 per ha). For further information on pruning and thinning practice in Queensland plantations refer to Robinson (1968) who has pointed out clearly that the application of thinning research programmes in routine practice has been much influenced by the market situation for saw and pulp logs.

3.52483

Basal Area Increment by years (Robinson,1968)

Basal Area control	Plot	Basal Area Increment - sq.ft.						
		1952-53	1953-54	1954-55	1955-56	1956-57	1957-58	Total 1952-1958
160 sq.ft.	3	6.1	9.1	12.0	9.7	7.7	5.8	50.4
	6	7.4	10.1	12.4	9.9	6.7	6.5	53.0
	Average	6.75	9.6	12.2	9.8	7.2	6.15	51.7
130 sq.ft.	7	7.2	10.7	12.8	11.0	7.3	6.4	55.4
	8	7.2	10.6	12.5	10.3	7.1	6.5	54.2
	Average	7.2	10.65	12.65	10.65	7.2	6.45	54.8
110 sq.ft.	1	6.0	9.4	10.6	9.9	7.6	5.2	48.7
	9	6.9	10.6	11.9	9.8	7.6	6.7	53.5
	Average	6.45	10.0	11.2	9.85	7.6	6.05	51.1
90 sq.ft.	2	6.9	7.4	10.2	8.0	7.7	4.7	44.9
	10	7.3	13.2	9.6	9.1	6.6	5.7	51.5
	Average	7.1	10.3	9.9	8.55	7.15	5.2	48.2
70 sq.ft.	4	6.5	7.4	8.1	7.3	4.4	4.3	38.0
	5	8.1	8.1	9.4	9.2	5.5	4.8	45.1
	Average	7.3	7.75	8.75	8.25	4.95	4.55	41.55

Number of trees per acre corresponding to the above basal areas

Year of thinning	No. per acre left after thinning									
	160 sq.ft.		130 sq.ft.		110 sq.ft.		90 sq.ft.		70 sq.ft	
	3	6	7	8	1	9	2	10	4	5
1951	525	550	525	570	420	420	330	310	225	225
1954	525	550	425	460	345	330	250	215	145	130
1956	460	475	340	365	275	265	145	130	115	100

The above general account of pruning and thinning prescriptions is not intended for general application in all situations, but it serves as a guide for foresters who are or will be handling Hoop or Klinkii Pines. However, what is more important is for each country to develop a pruning and thinning schedule suitable to its particular area.

3.6 Mensuration

3.61 Growth and Yield

3.611 Australia

Under suitable plantation conditions the growth of Hoop Pine is satisfactory though not rapid (Baur, 1962). The table on page 46 presented by Baur contains figures obtained from:

(a) assessment of 179 acres (72.4 ha) at Beaury (subtropical rainforest), one of the best Hoop Pine plantations in Northern New South Wales.

(b) assessment of 100 acres (40.5 ha) of established plantation at Bo Bo (submontane forest), where frost destroyed much of the original plantings.

(c) growth plot in a particularly good stand at Beaury

(d) growth plot at Mt. Pikapene (dry rainforest).

This table is important in that it indicates what might be expected from various sites under rainforest vegetation.

3.612 Papua - New Guinea

Growth and yield records are also available from New Guinea and the table on page 47 points to the growth potential of Hoop Pine in the Bulolo Valley, where large areas have been planted with Hoop Pine. The Bulolo Valley Hoop Pine was reported to be making excellent progress when 1963 measurement was made.

3.613 Yield of Provenances

Different provenances of Hoop Pine appear to exhibit variations in growth and yield potential. For example the following provenances of Hoop Pine planted in 1941 at Imbil at 9' x 8' (2.74 x 2.44m) at elevation of 400' (121.9m) with an annual rainfall of 52' (1320.8mm) and thinned in 1964 to 270 stems per acre (667 per ha) from 350 per acre (865 per ha) in 1957 and pruned to 8' (2.44mm) when 75 percent of the stems were 17' (5.18m) high, had a mean height of 83' (25.3m). See table on page 48.)

In spite of the comparatively excellent progress which Hoop Pine makes in New Guinea it is not very much favoured there. Instead A. hunsteinii is preferred to A. cunninghamii because although the former starts slower it later makes up on the latter and it is said to have a better form, small branches at first but developing larger branches in

Growth of Hoop Pine in Plantations on Rainforest Sites (Baur, 1962)

	Age yrs. (1)	Stems/acre (per ha) (2)	B.A./acre (per ha) (3)	Diam. = Mean B.A. (4)	Mean dom. ht. x/ (5)	Site Index +/ (6)	Merch. (per ha) Vol./acre (7)	Vol. M.A.I. (8)
			sq.ft. (sq.m)	in. (cm)	ft. (m)		cu.ft. (m^3)	cu.ft./acre (m^3/ha)
A	16	380 (939)	118 (27)	7.55 (19.1)	56 (17.07)	80	1881 (131.70)	117 (8.19)
B	18.5	360 (889)	99 (22.7)	7.10 (18.0)	48 (14.63)	60	1017 (71.16)	55 (3.85)
C	19	445 (1099)	182 (41.7)	8.65 (21.97)	65 (19.81)	80	3874 (270.97)	204 (14.27)
D	17	480 (1186)	123 (28.2)	6.86 (17.4)	64 (19.51)	80	2145 (150.09)	126 (8.82)

x/ Mean dominant height is the height of the 40 tallest stems per acre.

+/ Site Index classes are based on the mean dominant height at age 25 years.

Records from Yield Plots of A. cunninghamii in the Bulolo Valley (New Guinea)

1 9 6 2

				Basal Area/Acre sq.ft.				Volume/Acre cu.ft.				Predominant Height (ft.)			
Age (1)	Plot No. (2)	No. of stems (3)		Standing (4)		C.A.I. (5)		Standing (6)		C.A.I. (7)		Height (8)		C.A.I. (9)	
Years		Acre	Hectare	sq.ft.	sq.m.	sq.ft.	sq.m.	cu.ft.	cu.m.	cu.ft.	cu.m.	ft.	m.	ft.	m.
5.5	17 A	360	889	38	8.7	-	-	368	25.8	-	-	34	10.36	-	-
	B	341	842	44	10.1	-	-	485	34.0	-	-	39	11.89	-	-
6.5	9 A	410	1013	78	17.9	15	3.4	976	68.3	231	16.2	47	14.33	7	2.13
	B	335	828	70	16.0	16	3.8	897	62.8	286	20.0	47	14.33	9	2.74
7.5	11 A	390	963	95	21.8	19	4.4	1358	95.1	417	29.2	56	17.07	8	2.44
	B	323	798	91	20.8	21	4.8	1389	97.2	654	45.8	54	16.46	7	2.13
8.5	8 A	432	1067	105	24.1	16	3.8	1992	139.4	715	50.1	56	17.07	5	1.52
	B	313	501	78	17.9	19	4.4	1418	99.3	566	39.6	59	17.98	6	1.83
9.5	14 A	443	1092	114	26.1	13	2.9	2338	163.7	472	33.0	63	19.20	7	2.13
	B	335	828	102	23.4	16	3.8	2302	161.1	615	43.1	62	18.90	6	1.83
10.5	4 A	320	791	131	30.0	15	3.4	-	-	-	-	77	23.47	9	2.74
	B	159	393	82	18.8	12	2.8	-	-	-	-	76	23.16	10	3.05
12.0	2 A	515	1272	200	45.9	11	2.5	-	-	-	-	87	26.52	5	1.52
	B	189	467	109	25.0	11	2.5	-	-	-	-	85	25.91	4	1.22

1 9 6 3

6.5	17 A	349	862	53	12.2	15	3.4	569	39.8	217	15.2	40	12.19	3	0.91
	B	316	781	56	12.8	15	3.4	698	48.9	251	17.6	49	14.94	10	3.05
7.5	9 A	410	1013	94	21.6	16	3.8	1411	98.8	435	30.5	55	16.76	8	2.44
	B	335	828	84	19.3	14	3.2	1251	87.6	354	24.8	55	16.76	8	2.44
8.5	11 A	410	1013	107	24.5	15	3.4	2121	148.5	812	56.8	66	20.12	10	3.05
	B	307	758	103	23.7	16	3.8	2204	154.3	891	62.4	64	19.51	10	3.05
9.5	8 A	438	1082	115	26.4	16	3.8	2520	176.4	664	46.5	62	18.90	6	1.83
	B	303	749	92	21.1	16	3.8	2112	147.8	754	52.8	63	19.20	4	1.22
10.5	14 A	437	1079	137	31.5	13	2.9	n.a.	n.a.	n.a.	n.a.	66	20.12	3	0.91
	B	330	815	114	26.1	14	3.2	n.a.	n.a.	n.a.	n.a.	68	20.73	6	1.83
11.5	4 A	326	805	137	31.5	14	3.2	n.a.	n.a.	n.a.	n.a.	80	24.38	3	0.91
	B	154	380	91	20.8	9	2.1	n.a.	n.a.	n.a.	n.a.	77	23.47	1	0.30
13.0	2 A	515	1272	211	48.5	12	2.8	n.a.	n.a.	n.a.	n.a.	92	28.04	5	1.52
	B	180	445	112	25.7	8	1.8	n.a.	n.a.	n.a.	n.a.	88	26.82	3	0.91

n.a. = not available

Source: From Papua and New Guinea Department of Forestry, 1962/63 Annual Report

Yield of Provenances

Provenance	Source	Sept. 1964 Volume		C.A.I.		Mean G.B.H.		Height	
		cu.ft.	cu.m.	cu.ft.	cu.m.	in.	cm.	ft.	m.
A	Benarkin Brisbane Valley	3685	104.35	388	10.99	31.44	80.00	88.6	26.97
B	Yarraman, B.V.	3484	98.66	382	10.82	32.58	82.70	85.6	26.06
C	Gympie Mary Valley	3148	89.13	330	9.35	30.71	78.00	84.6	25.75
D	Jimma	3989	112.96	420	11.89	33.63	85.40	87.2	25.58
E	Gallangowan	3729	105.59	413	11.69	32.89	83.50	86.3	26.30
F	Kilkwan	2911	82.43	271	7.67	30.05	76.30	82.7	25.20
G	Kalpowar	3682	104.26	470	12.31	32.77	83.20	85.0	25.91
H	Warwick	3231	91.49	318	9.01	31.39	81.50	83.5	25.45
I	Control = Local stock								

heavy whorls later with up to 5' (1.52m) internode.

3.614 The yield table based on data from plots up to 40 years of age under combined pulp and sawlog operations is presented on page 50. (Hawkins and Muir, 1968).

3.615 Growth in Exotic Plantations

At the Muguga Arboretum, Kenya, Hoop Pine has been reported to be making good progress. Height growth in 8 years was 28' (8.53m) with average b.h. diameter of 3.4" (8.6cm). In the same arboretum a three year old Hoop Pine reached a height of 8' (2.44m) and its vigour and health was said to be good. However, a tree's performance in an arboretum may be quite different from its performance under plantation conditions.

Hoop Pine has also been introduced to several other countries including India, Malaya, Tanzania, Sabah and Trinidad. At present these trials are not on a large scale, but aim at exploring the possibilities of growing Hoop Pine on a commercial scale. In some of these places the performance of Hoop Pine has been reported to be good. Hoop Pine has long been planted (since 1870) in the Island of Mauritius where, with other conifers, it has been found that the Araucarias are very resistant to cyclones, even the severe cyclones of 1960 (Brouard, 1967).

Mauritius

There are now 400 hectares of Hoop Pine in Mauritius, most of which is between 10 and 20 years old. The rate of planting is however only 20 hectares per year because of the lack of suitable and available land at low altitudes (below 100m) where the tree shows the best growth. See table on page 51.

Nigeria

Kemp (pers. comm., 1968) has made a preliminary assessment of Hoop Pine trial plots established in the Jos Plateau, Nigeria, (about 4000' above sea level) where the annual rainfall is 55" (1397mm), but with a severe dry season. Planting distance was 8' x 8' (2.44m x 2.44m) and the plots were cultivated annually during the wet season. At the sixth year the general height and girth of the species were 12' (3.66m) and 7" (17.78cm) respectively and the height and girth of the dominants were 17' (5.18 m) and 9.6" (24.38cm) respectively. Kemp notes that early growth was very slow but has improved since the fourth year and seems to be still accelerating, and that the species is capable of withstanding the severe dry season well. But he thinks that increased soil fertility (especially nitrogen) may be necessary for satisfactory growth rates. This confirms Richards' view (op. cit) on the effect of nitrogen on the growth of Hoop Pine.

Rhodesia

For an assessment by Barrett and Mullin, 1968 (published after the completion of this text) see references page 139.

Yield Table - Hoop Pine 9' x 8' (2.74 m x 2.44 m) Site Index 85'

Age (yrs) (1)	Whole stand per acre (2)	Thinned per acre (3)	Retained per acre (4)	Pulp yield cu.ft./acre (5)	Mill logs cu.ft./acre (6)	Total yield cu.ft./acre (7)
13	500 (1235/ha)	150 (370.5/ha)	350 (864.5/ha)	500 (35 m^3/ha)	-	500 (35 m^3/ha)
18	350 (864.5/ha)	110 (271.7/ha)	240 (592.8/ha)	550 (38.5 m^3/ha)	-	550 (38.5 m^3/ha)
22	240 (592.8/ha)	40 (98.8/ha)	200 (494/ha)	200 (14 m^3/ha)	420 (29.4 m^3/ha)	620 (43.4 m^3/ha)
28	200 (494/ha)	40 (98.8/ha)	160 (395.2/ha)	170 (11.9 m^3/ha)	530 (37.1 m^3/ha)	700 (49.0 m^3/ha)
35	160 (395.2/ha)	40 (98.8/ha)	120 (296.4/ha)	150 (10.5 m^3/ha)	630 (44.1 m^3/ha)	780 (54.6 m^3/ha)
42	120 (296.4/ha)	20 (49.4/ha)	100 (247/ha)	50 (3.5 m^3/ha)	550 (38.5 m^3/ha)	600 (42.0 m^3/ha)
48	100 (247/ha)	20 (49.4/ha)	80 (197.6/ha)	40 (2.8 m^3/ha)	970 (67.9 m^3/ha)	1,010 (70.7 m^3/ha)
55	80 (197.6/ha)	80 (197.6/ha)	-	170 (11.9 m^3/ha)	7,000 (490 m^3/ha)	7,170 (501.9 m^3/ha)
				1,830 (128.1 m^3/ha)	10,100 (707.0 m^3/ha)	11,930 (835.1 m^3/ha)

Provisional Figures of Growth and Yield for *Araucaria cunninghamii* in Mauritius

(Supplied by Brouard 1968)

Age (yrs.)	Main crop after thinning					Thinnings		Total volume/ ha. O.B. (m^3) incl. thinnings	Annual vol. inc./ ha. O.B. (m^3)	
	Height (m) Dominant	Height (m) Mean	Mean G.B.H. O.B. (cm)	Stocking s.p.h.	Total vol./ha. O.B. (m^3)	Vol. removed/ ha. O.B. (m^3)	Total vol. removed to date/ha. O.B. (m^3)		C.A.I.	M.A.I.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
				Quality class I (upper)						
10	9.2 - 12.2	7.5 - 10.7	42 - 51	1,000 - 1,500	50 - 70	0 - 18	0 - 18	50 - 85	12	7
15	12.2 - 15.2	11.5 - 13.7	55 - 64	750 - 875	85 - 105	18 - 35	18 - 50	105 - 160	23	9
20	15.2 - 18.2	14.5 - 16.7	67 - 77	500 - 625	140 - 175	35 - 70	50 - 125	190 - 300	41	12
25	18.2 - 21.5	17.5 - 19.7	80 - 89	250 - 375	230 - 280	70 - 140	125 - 270	355 - 550		18
				Quality class II (lower)						
10	6.2 - 9.2	4.5 - 7.5	33 - 42	1,125 - 2,000	35 - 50	0 - 18	0 - 18	35 - 70	12	5
15	9.2 - 12.2	9.2 - 11.5	45 - 55	875 - 1,000	70 - 85	18 - 35	18 - 50	85 - 140	18	8
20	12.2 - 15.2	12.2 - 14.5	58 - 67	625 - 750	105 - 140	35 - 50	50 - 105	160 - 255	31	11
25	15.2 - 18.2	15.2 - 17.5	70 - 80	375 - 500	175 - 230	50 - 100	105 - 210	280 - 440		15

3.7 Protection

3.71 The Elements

3.711 Fire

Hoop Pine is very susceptible to fire and every precaution should be taken to exclude fire from the plantation throughout the rotation. This means that adequate fire protection should be planned. Such a protection system includes external and internal firebreaks and the provision of water reservoirs at suitable areas throughout the plantation. In New Guinea green breaks for fire protection are provided. These breaks are 3 to 5 chains (Gunter's chain) (60. 35 m to 100. 6m) wide and where possible are located on unplantable sites.

3.712 Wind

Hoop Pine is probably the most cyclone resistant exotic tree grown in Mauritius. It generally stood up fairly well even to the cyclones of February 1960 when winds in gusts reached, and probably exceeded, 250 km (156 miles)per hour. Relatively few Hoop Pine were broken or uprooted then. Many tops and branches were broken, but most of the trees recovered fully within three or four years. The trees shed their branches one by one during a severe cyclone, leaving only the bare stem; new branches eventually grow again from epicormic shoots and replace the casualties. However, at very high elevations Hoop Pine is not wind firm, especially in young plantations.

3.72 Insects

3.721 Vanapa oberthurii

This insect is known as the Hoop Pine weevil in New Guinea and its attack has been observed at Bulolo and Wau plantations, where it makes galleries in the wood. White and Cameron (1965) have described the life history of Vanapa in a short note as follows:

The egg stage lasts for about ten days. The egg is large and is laid in a crevice in a small hole near a resin flow or under a loose outer bark and then covered with a cemented masticated bark. The larval stage lasts about five months and is passed largely in the bark. The tunnels are branched and are made vertically. After about five months a hole is bored into the wood for 1. 5" (3. 81cm) and then up and outwards for approximately the same distance. The insect bores a hole through the bark at the entrance to allow the disposal of wood pieces while the upward part of the horizontal entrance is plugged with wood pieces from the pupal chamber. These pieces are laid parallel in a vertical direction and are removed by the emerging adult. The pupal stage lasts about one month and the adult may remain two to four weeks in the chamber before making its way out. An adult could probably develop in six months when the wings are well developed; they probably feed on the green bark of Hoop Pine twigs.

Control of Vanapa may be effected through many agencies. For example, many larvae are drowned by resin when attempting to bore into the bark. It has been suggested that click beetles could attack Vanapa larvae and while parasites have not been known to attack the larvae there are indications that some bacteria, fungi or even viruses might be responsible for the death of many larvae. Heavy and continual attack has been noted at Bulolo during excessively dry periods and natural limiting causes may have been weakened during such dry weather.

In New Guinea the routine treatment when there is a Vanapa outbreak is as follows:-

(i) all infested trees are felled and the larvae extracted

(ii) the area affected is visited again within a few days and an insecticide is applied to destroy any adult weevil attracted to the area

(iii) adjacent trees are checked at three-monthly intervals to remove further infested trees

(iv) during thinning operations care is taken to ensure that any adults feeding on the foliage are destroyed by spraying with a 2.5% solution of D.D.T.

3.722 Setomorpha rutella Zell

The larvae of this insect have been detected in Hoop Pine seed. Ten percent of the seed may be infested. Possible control measures are being investigated in New Guinea.

3.723 Hylurdrectonus araucariae

A small scolytid beetle called Hylurdrectonus araucariae has been observed on the leaves and bark of Hoop Pine in New Guinea plantation between 3609' and 4429' (1100 m and 1350 m) altitude. The attack is confined to plantations 12 - 15 years old and to trees 49' to 59' (15 m to 18 m) high. The beetle can cause complete defoliation of Hoop Pine. It is not only confined to plantations but also occurs in the natural Hoop Pine forests. Because the attack is mostly confined to plantations on poor sites, Morel (1967), has suggested that in order to limit the attack care should be taken in the choice and selection of suitable planting sites.

3.724 Aesiotes notabilis
(Hoop Pine Bark Weevil)

This weevil is common in Hoop Pine plantations in Australia. It can cause serious trouble if green pruning is done out of season and for this reason pruning in Queensland is restricted to the period 1st May to 31st August. To prevent the spread of the attack damaged stems are painted with creosote plus oil on a 50/50 mixture. There is no report yet on the biology and life history of the weevil.

3.725 Miliona isodoxa
(a moth)

The larvae of this insect are defoliators. There are at present no practical control measures and natural enemies have been found to be very useful in keeping the number of the larvae in check.

3.726 Coptotermes elisae
(Hoop Pine termites)

This termite is said to inhabit up to ten percent of the boles (butt section usually) of Araucaria at Bulolo, New Guinea. The termites enter stumps and logs during plantation clearings and gradually their population builds up. But as food supply dwindles (usually three-five years after felling) they turn their attention to plantation trees. The attack is through damaged or diseased roots underground and an active lattice of channels on the tree trunks indicates an early stage of attack. At later stages a termitarium (termite colony mound) is developed near ground level inside the tree and the base is hollowed to within a quarter of an inch of the bark. The trees fall over easily at this stage.

Control Measures

Stump Control In New Guinea effective stump and log treatment is still being investigated. But efforts are made to ensure that all logs are removed from the bush or destroyed by heaping and burning.

Plantation Control Trees with fresh galleries at the base containing termites are sprayed with an 0.03% solution of dieldrin. Holes are bored at the base of trees with old mud galleries (not containing termites) and one pint (about 0.6 l) of 0.03% solution of dieldrin is poured into the termite nest. The hole is plugged with grease or grafting mastic. Where possible the central termitarium should be located and destroyed.

3.727 White Grubs

These are said to be one of the most serious insect pests in Hoop Pine nurseries both in New Guinea and Australia. In Australia they are controlled by treating the bed with Arsenate of Lead. Six pounds (2.72 kgs) of Arsenate of Lead are mixed with a barrow load of Hoop Pine sawdust (any other suitable sawdust would do) and spread over each bed 50' x 10' (15.24 x 3 m), this is dug in just prior to sowing. The treatment is repeated at approximately six-year intervals.

In New Guinea gammexane is used in the control of white grubs (0.45 kg) of gammexane is mixed with 50 gal. (227.3 litres) of water and this solution is sprayed at the rate of 1 gal. (4.5 litres) of the solution to a bed at the time of turning the bed.

3.728 Grasshoppers

These can be controlled by laying down baits. In Australia the following formula has proved adequate:

½ lb (0.22 kg) of Arsenate of Lead
4 lbs (1.81 kgs) of Molasses
25 lbs (11.34 kgs) of Bran
2½ gals. (11.35 litres) of Water

The Arsenate of Lead is dissolved in a pint (0.56 litres) of boiling water in a suitable container, and the molasses is mixed in a similar manner. Both solutions are thoroughly stirred, and half of the water is added cold to each container and stirred again. Finally the molasses mixture is added to the arsenical solution and stirred. The bran is then spread on a mixing board and the solution is added to it, the whole being mixed thoroughly until a moist loose mash is obtained. The consistency of the mash should be such that it allows it to trickle readily through the fingers. The bait so prepared is scattered broadcast where young grasshoppers are present.

3.729 Mole Crickets

The control of this insect pest can be effected in the nursery by the use of Chlordane or Gammexane. In Australia, the former is preferred. Chlordane may be obtained as an 80 percent concentrate under various trade names. It should be applied to beds at a concentrate of 2 percent, i.e. 4 fluid oz. of the concentrate is diluted with water to make up 1 gallon (4.5 litres) of spray. This should then be lightly sprayed on the bed surface at the rate of 50 gallons per acre (561.7 litres per hectare).

The whole bed may be sprayed if germination has not occurred, but in other cases the spray should be directed onto the space between rows of plants because young soft plants may be damaged when heavily sprayed with Chlordane. It is not necessary to cover the whole bed completely with the insecticide in order to obtain the best results and after application the Chlordane may be deposited in the soil as it is not affected by watering since it is insoluble.

Chlordane, like most organic insecticides, is poisonous to humans in sufficiently high concentrations and adequate preparations must be taken when using it. Spray drift should not be inhaled; it should not touch the skin and where it does the part affected must be thoroughly washed with soap as soon as possible. Clothes on which Chlordane has been spilt should be washed before wearing and the insecticide should not be allowed to come into contact with eating utensils.

3.730 Cutworms

Damage by cutworms may be confined to freshly sown seed beds where the first cotyledon and seedling shoot are eaten including the hypocotyl (that portion of the seedling below the cotyledons). At this stage the damage is said to resemble that caused by grasshopper or by mole crickets. The presence of cutworm can be detected from a slightly raised area of the soil or sawdust at the base of the seedling. It is in this raised area that the pest is found. At a later stage the larvae of the cutworm cuts and pulls the seedling downwards, leaving the cotyledons resting on the soil surface and the damage'is similar to that caused by mole crickets or by small white grubs.

Cutworm damage can therefore be easily mistaken for that of grasshopper, crickets or white grubs. It is essential that the right pest is identified and correct treatment applied. Cutworm can be controlled by the use of the same bait as prescribed for grasshopper (see paragraph 3.728 above).

3.731 Mealy Bugs

These have been observed to cause damage to Hoop Pine nurseries and can be controlled by means of a nicotine sulphate spray prepared by mixing 1 oz. (28.3 grams) of nicotine sulphate, 3 ozs. (85.0 grams) of soap and 5 gallons (22.7 litres) of water. Another method is to spray the bugs with detergent.

3.74 Damage by Animals

In Queensland, Australia, rats can cause serious damage to Hoop Pine plantations. In stands up to 7' (2.13 m) high the damage consists of digging and burrowing around the roots of the trees and the eating of the bark from the roots. In some cases the damage to the root system can be sufficiently severe to cause the death of the tree and in many other cases the burrowing and digging so loosens the tree in the ground that it falls over. In stands taller than 7' (2. 13 m) the damage consists of the eating of the bark at ground level, in many cases resulting in the ringbarking of the tree.

Damage may be controlled by means of baits and in Queensland a special bait known as "1080" is laid on a 10 yard (9. 14 m) grid.

Brouard (personal communication with Lamb) has stated that in Mauritius snails and slugs, particularly the giant Achatina snail, are very fond of the bark of Araucaria seedlings, both in the nursery and in the field. He suggested that in order to reduce the damage done by these pests, Araucaria seedlings should remain in the nursery for at least two years before planting them out in the field, thus allowing for a hardening of the bark, which then becomes too tough to be damaged by the snails.

3.75 Fungi

3.751 Fomes noxius
(Root Rot)

This fungus causes root rot and consequently the death of plants from age three years onwards. It is common throughout Hoop Pine plantations in New Guinea.

Infection spreads from infected stumps of previous forest and the fungus invades through the root system. The foliage of an infected tree becomes olive green and later red orange in death. No practical control has been found possible other than the digging out of infected trees. But as the trees in the plantation become older there appears to be a lessening of the attack and it is not noted in areas of 10 years old. However its spread, mainly through spores, can be effectively controlled by treating cut stumps with creosote.

3.752 Damping-off

This is a disease caused by a variety of soil inhabiting fungi. Several species of fungi may be involved but in general the attack results in the death of seedlings. In Australia three main types of damping-off have been observed:-

a/ Pre-emergence damping-off In this the seed may fail to germinate or the radicle of the seed is attacked as it develops and the cotyledon fails to emerge. The seedling is then killed before it appears above ground.

b/ Ordinary damping-off After the seedling and its soft stem bearing the cotyledon appear above ground the fungus penetrates the roots and grows up the stem. This causes a constriction of the stem at about soil level and the seedling falls over.

c/ Top killing The fungus forms a mat over the top of the seedlings and smothers them. This is prevalent when there is much moisture and especially when stocking is very dense.

Prevention

Damping-off may be prevented by:-

1. avoiding excess moisture in the soil and overshading of the beds

2. weeding frequently and regulating seedling density

3. using only well rotted organic manure

but when it has occurred it may be checked by use of chestnut mixture prepared by mixing thoroughly 2 parts of powdered blue stone and 11 parts of fresh powdered rock ammonia (ammonium carbonate). These are kept in a tightly stoppered glass or earthenware vessel for at least twenty-four hours before use. For use the dry mixture is dissolved in water at the rate of 1 oz to 2 gallons (28. 3 grams to 9. 1 litres) and the solution is watered on the soil at the rate of 2 gallons per 3 square yards (9. 1 litres per 2. 51 sq. m).

Thiotox and Captan are other suitable fungicies for the control of damping-off. In New Guinea Cuprox is used and is applied at the rate of 3 ozs per 4 gallons of water (85 grams per 18. 2 litres).

3. 753 Collar Rot

Seedlings of Hoop Pine are occasionally attacked and killed by fungus known as "collar rot" caused by Sclerotium rolfsii. The first symptoms of the attack are a bronzing and drooping of the foliage, followed by wilting and death. This fungus is very virulent and is capable of rapid spread from one section of the nursery to another by tools and boots of nursery workers.

3. 754 Root Rot (see para 4. 742)

3.755 Die back

Die-back of A. cunninghamii caused by Botryodiplodia theobromae Pat. has been reported in Malaya. This pathogen was isolated from diseased branches of Hoop Pine, by Griffiths (1966). The symptoms in the diseased trees were characterized by withered brown leaves with the terminal whorl of branches most commonly affected. Cuts made into the affected branches showed that the wood was discoloured blue or blue/black. After a series of experiments with the pathogen Griffiths concluded that the disease becomes established only in plants which are weakened either by changes in the environment or by the presence of a primary invader. It does not attack healthy trees and the disease is not likely to become serious.

4.0 ARAUCARIA HUNSTEINII K. SCHUMANN

(Syn. A. klinkii Lauterbach)

4.01 Local Names

Rassu or Pai

4.02 Trade Name

Klinki Pine

4.1 Distribution

A. hunsteinii is indigenous to New Guinea where it is found growing in the mountainous areas at elevations of 610 m - 1525 m (2000' - 5000') above sea level. It is found in the same locality as A. cunninghamii. Both species, occupying an area of some 40,000 acres (16,190 ha), are common in the mountains near Finschhafen and on the hills of the Upper Ramu River. It reaches its best development in the Wau-Bulolo district at elevations between 760 m and 1220 m (2500' - 4000') (Anon, 1951). It is confined to the Jimmi Valley in the north-west and Milne Bay in the south-east in latitudes 5^{o} - 10^{o} South (Havel, 1965).

4.2 The Tree

A. hunsteinii forests contain magnificent trees often growing well in close stands. The tree grows to heights of from 46 m to 85 m (150' - 280') with clear cylindrical bole up to 43 m (140') to the first whorl of branches.

Bole: Straight and cylindrical and about half of the total height. It provides sound timber of which a high percentage is classed as first grade plywood logs, free of knots (Anon, 1957).

Bark: Often more than 1 inch thick, reddish brown, rough and exudes a colourless resin copiously. The inner bark is a rich red that pales to pink in its deeper portion (Gerry, 1954).

Crown: A loose pyramidal form with leaves tending to be at the tips of the branches.

Girth: Girths at breast height at maturity range up to 6 m (about 20') and diameters around 3 m (9') are very common.

4.3 Habitat Conditions

4.31 Climate

4.311 Rainfall

In Bulolo and Wau districts of New Guinea where A. hunsteinii reaches its best development the mean annual rainfall is 1600 mm (63") and 1854 mm (73") respectively. There is no strongly pronounced dry season as no month has an average below 76 mm (3"), although the driest period of the year is experienced from May to September, (Anon, 1966). However, there are differences in the magnitude and pattern of rainfall between Bulolo and Wau. These two districts are situated in a mountain valley and lie in the rain shadow of the nearby mountain. The rainfall at Bulolo is not markedly seasonal but there is a heavier fall (November to April) amounting approximately to two-thirds of the annual total. Wau differs from Bulolo in that the annual rainfall is about 250 mm (10") higher.

4.312 Temperature and Relative Humidity

Maximum temperatures are similar both in Bulolo and Wau and they do not vary markedly with season, being in the vicinity of $90^{o}F$ ($32.2^{o}C$) for all months. The following temperature and humidity figures have been recorded for Bulolo:

Temperature and Humidity (mean monthly) for Bulolo

	Temperature	Relative Humidity	
Maximum	$83^{o}-90^{o}F$ ($26.6^{o}-32.2^{o}C$)	9 a.m. 82%	3 p.m. 61%
Minimum	$64^{o}-66^{o}F$ ($17.7^{o}-18.8^{o}C$)	9 a.m. 72%	3 p.m. 49%

The above figures show that 9. a. m. humidities are high and the 3 p. m. humidities are markedly lower in Bulolo than anywhere else in the region. This has been attributed to a combination of rain shadow and altitude effect.

4.32 Edaphic Factors

The major rocks in the area carrying A. hunsteii are derived from pleistocene lacustrine (lake) deposits and they include mudstones, sandstones and conglomerates. It is believed that during the period of sedimentation, volcanic breccias and tuffs were deposited within and above the lake deposits. Recrystallised limestone deposits such as phyllites, schists and clitorite schists are common in the Bulolo Gorge.

Soils formed on the lake and alluvial deposits are of generally heavy texture, loamy clays to clay loams. The drainage is moderate and there is a tendency towards alkalinity. It has been suggested that where there is a choice of soils for nurseries and for plantation establishment those which are alkaline should be avoided (Basden, 1960).

4.33 Physiographic Factors
(Topography)

A. hunsteinii occurs mainly on the slopes of the inland valleys in Papua and New Guinea where the area devoted to forestry is generally steep and in some places precipitous. The predominant topographical features in the areas where A. hunsteinii is at its best are the Bulolo and Watut rivers and the ridge, the Manki Divide, which separates them. This ridge rises from 610 m (2000') at the junction of the rivers to over 2, 378 m (7, 800') at Mt. Kaindi (Southeast of Wau) (Anon, 1966).

4.34 Ecological Associations

A. hunsteinii and A. cunninghamii are found in the same locality but not equally mixed. Both species tend to be gregarious with one species or the other predominating. For example, in the Jimmi Valley, A. hunsteinii has been found to be widespread and A. cunninghamii rare, if present at all. A. hunsteinii is usually found in association with some rainforest species (and forming a dispersed emergent canopy) such as Endiandra, Antiaris, Argyrodendron, Toona, Celtis, Cryptocarya Cryptomeria, Dysoxylum, Flindersia pimenteliana, F. macrocarpa, Firmiana papuana, Ficus, Geijera salicifolia, Pometia and Pouteria. In general A. hunsteinii at its lower altitudinal limit mixes with lowland rainforest species, mainly of the drier type and at its upper limit it reaches into the lower montane oak forest, (Havel, 1965). In the Bulolo district natural regeneration is present but not sufficiently abundant to warrant its use in silvicultural operations, (Haji Ali, 1964).

4.4 Life History and Development

No history is available but see para 3.4.

4.5 Silviculture

4.51 Natural Regeneration

Although extensive areas of virgin forest of A. hunsteinii exist in Papua and New Guinea natural method of regeneration has not been given much, if any, consideration. Natural seedlings are present in the forest floor but apparently these are not sufficiently abundant for use in regenerating the forests. Emphasis is therefore on plantation establishment by artifical methods.

4.52 Artifical Regeneration

In spite of early difficulties A. hunsteinii has proved adaptable to plantation techniques. These techniques are those at present employed in Papua and New Guinea, and the following descriptions are based on the latest publications from that country by White and Cameron (1965).

4.521 Seed

See para 1.243.

4.5211 Seed Trees

These are trees from which seeds for sowing should normally be collected. Seed trees should be healthy, vigorous and of good form (bole and crown); diseased or malformed trees should be avoided. In New Guinea, trees have been classified as follows for the purpose of seed collection:

(a) Young trees - these have a dense conical crown.
(b) Young Mature - characterised by dense crown, paraboloid in outline, bearing the heaviest crop of seeds.
(c) Late Mature - with umbrella shaped crown of medium density.
(d) Senescent - with crowns in various stages of disintegration.

It is reported that the best seeds come from (b) type of tree although (a) and (c) may be satisfactory.

4.5212 Seed Collection

Observations in New Guinea indicate that the best time to collect seed cones is late September to early October. The timing of seed collection is very important because in early collections (i.e. before the middle of September) most cones are too immature and those that are mature are virtually devoid of fertile seeds; in late collections (i.e. after the middle of October) many cones are lost due to disintegration and those remaining contain fewer fertile seeds. In New Guinea cones collected at the peak of the season, about mid-September, yield about 30,750 fertile mature seed scales per tree.

Collected seed cones are allowed to dry by spreading them on appropriate shelves where they disintegrate, releasing the seedscales. The seedscales are turned over daily and those cones which fail to disintegrate within ten days are discarded. If during the drying any insect attack is observed the cones are dusted with an appropriate insecticide such as Gammexane.

4.5213 Seed Storage and Transport

It is the practice in New Guinea to sow the seeds immediately after collection and drying as the seeds are like those of A. angustifolia, markedly short-lived under high temperatures. But where it is not possible to sow immediately the seeds must be stored appropriately. Under atmospheric conditions A. hunsteinii seed loses its viability at the rate of 10 percent or even more a week during the first four weeks and thereafter the loss of viability increases rapidly so that at eight weeks after collection the viability is completely lost. The seeds should, therefore, be stored under cold, moist and airtight conditions at a temperature of 38°F (3.30°C). Experiments carried out in New Guinea on the storage of A. hunsteinii seed gave the following results.

Nature of Storage	Period	% Retention of Viability
Open at room temperature	2 weeks	50
Sealed at room temperature	2 weeks	50
Open at 38°F	6 weeks	50
Sealed (dry) at 38°F	9 months	50
Sealed (moist) at 38°F	18 months	50

Viability is retained for less than a week after removal from cold storage when deterioration is even more rapid. However, A. hunsteinii seed unlike A. cunninghamii does not tolerate very low temperatures such as 10°F (-12.2°C) (Havel, 1965).

Since it takes Klinkii Pine cones about ten days to disintegrate completely it is suggested as an experiment that cones should be despatched to the importing countries as soon as they are collected. Disintegration will be completed in receiving countries and the seeds sown there immediately. The cones should be packed with light weight material under cool storage conditions and transported by air in the passenger compartment to avoid freezing. It is hoped that the extra expense incurred by importing cones plus seeds would be compensated by the higher germination percent that would be obtained by sowing immediately. It would also relieve such an importing country of the necessity of maintaining expensive seed storage facilities.

4.522 Seed Germination

The germination capacity is fairly high when the seeds are sown immediately after collection or have been properly stored. Experiments dealing with the effect of delays in sowing under normal atmospheric conditions of temperature and humidity on the germination capacity, produced the following results:

Period between collection and sowing	Germination %
1 week	89.9
2 weeks	80.1
4 weeks	67.7
6 weeks	28.0
8 weeks	2.9
12 weeks	Nil

These experiments clearly indicate the need for early sowing and proper storage conditions.

4.523 Seedlings

The seedlings have a tendency to develop strong taproots and are slow to produce lateral roots. There is thus an unsatisfactory top:root ratio which is one of the main causes of poor survival on transplanting (Havel, op. cit).

4.524 Nursery Technique

4.5241 Preparation of Bed

In New Guinea a permanently shaded nursery bed measuring 54' long by 4' wide (16.5 m x 1.2 m) and raised 8" (20 cm) above the path, is the standard. The bed is provided with a frame to hold shade 30" (76 cm) above the ground. For the successful production of seedlings special care is required in the preparation of the seed-bed soil. The nursery should be sited on light loam, deep, fresh and porous. Heavy clay soils which lack aeration should be avoided.

It has been found that the physical characteristics of the soil are more important than the chemical composition since the latter can be improved by the application of fertilizers. And where the soil is heavy textured with poor structure it can be improved by the addition of a 2 inch (5 cm) layer of sharp river sand(without silt), 1" - 2" (2.5 cm - 5 cm) layer of sawdust (in New Guinea A. hunsteinii or A. cunninghamii sawdust is used) well mixed and, where the soil is alkaline (above pH 7.0), 15 lbs (6.8 kg) of sulphur per 200 sq. ft. (18.6 m^2) of bed may be applied. It is recommended that where soil improvement is required six weeks should elapse between the addition of sulphur and any other improvement such as the addition of sawdust.

The best soil pH for A. hunsteinii is 6.0 to 6.5 and it is necessary to test for pH eight weeks before sowing. When soils do not require any improvement, they should be dug over to a spade depth and all weeds removed; beds should lie in the rough for at least one week and then be dug again, breaking all clods and working the bed to a fine tilth. A day before sowing the bed surface should be loosened, levelled and then given a light watering.

4.5242 Treatment of Seed

See paras 3.5213 and 3.5232.

4.5243 Sowing of Seeds

In New Guinea seeds are sown in October to November when rainfall is sufficient to reduce watering to a minimum. There are three methods of sowing the seeds, (a) broadcast, (b) in drills 6" (15 cm) apart and (c) directly into tubes of compacted loam. But broadcast method is the standard method in New Guinea and the density of sowing is aimed at a stocking of 8 - 12 plants per square foot (85 - 130 per m^2) of bed space, that is 1600 to 2400 plants per bed.

It is the practice in New Guinea to cover the beds with A. hunsteinii or A. cunninghamii sawdust (at least three weeks old) to a depth of $\frac{3}{4}$" (2 cm) and to spread the sawdust uniformly over the entire bed. In Kenya Pine sawdust is used to cover the seeds of A. cunninghamii. However, it is not expected that A. hunsteinii or any other softwood sawdust would have to be imported by countries introducing A. hunsteinii for the first time. Sawdust from hardwood species may be equally suitable provided it is treated with a fungicide.

4.5244 Shading and Watering

Newly sown beds should be given full overhead shade within three days and preferably on the day of sowing. It has been found that the best shoot development occurs when the seed-beds are given 75% shade for the first few months and 50% shade for the next three months. Shading should be removed in two steps following this to give full exposure two weeks before tubing. Seed beds should be given initial heavy watering,followed by light watering two or three times per week for the entire germination period. Excessive watering however results in poor aeration and assists the development of root rot. The soil should be kept moist but not wet.

4.5245 Thinning

The number of seedlings should be reduced to leave twelve plants per sq. foot (130 per m^2), that is about 2,400 per bed. This should be done about four months after germination in New Guinea.

4.5246 Weed Control

The importance of keeping seed beds free from weeds needs no stressing. It is recommended that where possible levelled and prepared nursery beds should be watered heavily prior to sowing and the resultant weed crops diminished by spraying with white spirit at the rate of one pint (0.56 litres) per 200 sq.ft. (18.5 m^2). Where a further crop of weed seeds germinate shortly before or concurrently with the germination of A. hunsteinii seedlings, post-emergent spraying with white spirit at the same rate is necessary before the seedlings shed their coats. A. hunsteinii seedlings have a low resistance to weedicides and weeding should be done intensively by hand and care should be taken to avoid the introduction of weed seeds in manure and top-dressing.

4.5247 Tubing, Lifting, Grading and Root-wrenching

A. hunsteinii is not vigorous if planted as a bare-rooted seedling and it is said to have poor coppicing power (Haji Ali op. cit). Tubing is therefore necessary. 'Tubing' is a termed coined by Australian foresters to describe the transfer of seedlings from the seed bed to a column of soil held by a metal, plastic or bamboo tube (Havel op. cit). In tubing a light textured soil with reasonable supply of plant food is required. A sandy potting medium gives the optimum shoot:root ratio. Heavy soil is not suitable and should be avoided; optimum soil pH is 6.0 to 6.5. Sandy soil contains approximately 54% course sand, 28% fine sand, 11% silt and 7% clay (Haji Ali op. cit). It is estimated that a tubed stock for a 400 acre (162 hectares) project would require over 100 tons of tubing soil.

Tubing should be done at least 5 months before planting in the field when the majority (75%) of the seedlings are 6" to 9" (15 - 23 cm) tall, and in dull rainy weather. Periods of high wind and/or low humidity should be avoided.

In lifting the plants for tubing care should be taken to minimize damage to the roots and at the time of lifting it is essential that the soil should be moist and loosened. Part of the bed being lifted should be in complete shade and lifted plants should be adequately protected from air and light within the folds of a wet bag.

Lifted plants should be graded and only the standard stock 6" - 9" (15 - 23 cm) high should be tubed. Size has an important bearing on the survival of seedlings in the field. The method of tubing in Queensland and New Guinea is as follows: the tube opens down one side and it is half-filled with soil. The plant is laid on this soil with the root collar in line with one end of the tube. More soil is added ensuring that all air pockets are eliminated and the soil is packed firmly round the roots. The tube is clipped shut and placed upright on the bed. Zinc tubes $1\frac{1}{2}$ inches (3.8 cm) diameter by 8" (20 cm) tall are used. Bamboo and polythene tubes may also be used where galvanized iron tubes are not available.

It is the practice in New Guinea to place tubed stock at a spacing of 8" to 2" (20 x 5 cm), measured from stem to stem. Newly tubed plants should not be placed more than 2" (5 cm) in the soil and they should be given full shade. The shade should be gradually removed to give full light at least one month before transferring to the planting site. Following tubing the soil should be kept moist by watering. Two inch galvanized wire-netting stretched about four inches above a hard floor is being used to support the standing tubes. There is no mention of root wrenching and pruning but it is assumed that when tubes are stood on a hard foundation, any roots extruding from the tubes are periodically cut off.

4.5248 Factors Influencing the Survival of Seedlings after Transplanting

Before dealing with the plantation establishment of *A. hunsteinii* it would be necessary to summarize the more important factors which determine its survival in the field. The method of raising *A. cunninghamii* in Australia was applied to the raising of *A. hunsteinii* in New Guinea. In the case of transplanting this involves a two-stage transfer known as tubing. In the first stage the seedlings are transferred from the seed bed to a column of soil held by a metal tube and this is done in the nursery under shade with adequate watering. In the second stage the transplant, together with the undisturbed column of soil is planted out in the plantations. Initially the survival of *A. hunsteinii* transplants was markedly lower than that of A. cunninghamii and Havel (1965) has now found that the following factors influence the survival of seedlings after transplanting:

(i) Unsatisfactory shoot:root ratio due to the slow development of lateral roots and strong taproot which is unavoidably damaged in the lifting of the seedlings. Experiments have shown that light-textured soil is essential to the development of lateral roots and hence the survival after tubing. Root wrenching several months before tubing is advocated.

(ii) Size and age of seedlings. This has an important bearing on their survival after transplanting. The larger seedlings with unfavourable shoot:root ratio are less capable of overcoming the disturbance (physiological) of transplanting from seed bed to tube. Fifteen months is the optimum age for tubing in order to obtain the highest proportion of suitable seedlings 6" - 9" (15 - 23 cm) high. But with improved nursery soil, faster growth may be achieved so that the optimum size of 6" - 9" (15 - 23 cm) high would be reached in 9 - 15 months.

Experimenting should be carried out to find out if much earlier transplanting to tubes would not give even better results. Transplanting as soon as the plants are large enough to handle (as is done in Pine nurseries) is suggested.

4.525 Plantation Establishment

4.5251 Planting Area

It is advisable to restrict the planting of A. hunsteinii to land previously bearing high forest. Experience in New Guinea has shown that A. hunsteinii tops may blow out in strong winds, therefore it should not be planted on ridge tops or in areas where strong winds can be expected.

4.5252 Site Preparation

The area to be planted should be felled well in advance, depending, however, on the scale and season of operation. Operations will usually involve brushing, felling and burning to dispose of the felled material. In general the area should be reasonably clean so that planting and subsequent tending operations are not hampered by 'bridge' logs and branches projecting above the ground. In areas subject to termite attack every effort should be made to secure a thorough burn as this would reduce the amount of woody material and hence will assist in reducing the termite population. Operations such as ploughing will seldom be economic on sites cleared of high forest because of the cost of stump removal.

4.5253 Planting

Season: Planting should normally begin as soon as possible after theburn when the soil conditions are favourable, i.e. when the soil is damp in the top 8" - 10" (20 -25 cm). It is recommended that planting should cease if no rain falls for about one week and during periods of hot dry winds.

All A. hunsteinii plants should be planted tubed and it is essential that this planting should be carried out without any disturbance of the cylinder of soil surrounding the roots when removing the tube. Both shallow and very deep planting have an adverse effect on the survival of transplants. Shallow planting which exposes a portion of the stem previously embedded in the cylinder of the soil is harmful and should be avoided; slightly deeper planting is not harmful to A. hunsteinii. It is however recommended that plants should not be planted deeper than 1" (2.5 cm) below normal level.

4.5254 Spacing

In New Guinea, the planting spacement is 9' x 8' (2.8 x 2.5 m), that is 9' (2.8 m) between rows and 8' (2.5 m) between plants. This spacing represents about 600 trees per acre on reduced horizontal measurements and on moderate slopes. But allowance should be made for slope in measuring distances between rows and along rows.

4.5255 Size of Plants

The effect of the size of planting stock on the survival of transplants has been mentioned in para 4.5248. In New Guinea the minimum size of planting stock is laid down as 9" (2.3 cm) high and the maximum as 24" (61 cms). It has been found that the most satisfactory stock for planting out is large 2-year-old stock 12" (29.5 cm) and higher. But it would be useful to establish experimentally the optimum size of planting stock for each locality into which A. hunsteinii has been introduced. Havel (1965) has found out that the mortality rate of planted stock was significantly higher in the one-year-old stock than for the two-year-old stock. This is because in the one-year-old stock the lateral roots are not developed, whereas those of the older stock are well developed and have a strong hold on the core of soil surrounding them.

4.5256 Beating up

See A. angustifolia para 2.5245.

4.5257 Planting Experience in New Guinea and Malaya

4.52571 New Guinea

In the Bulolo/Wau area about 11,373 acres (4,601 ha) of Klinkii and Hoop Pines have been planted, and of this area about 20% is Klinkii Pine. The annual planting programme is 1250 acres (506.13 ha). In the opinion of two forest officers, Evan Shields and D.H. MacKintosh (personal communication with Lamb) Klinkii Pine should be preferred in New Guinea to Hoop Pine because, though Klinkii Pine grows more slowly in early youth it overtakes Hoop Pine later, has a better form and promises greater volume production on suitable sites. Mitchell (1963) expresses a similar opinion on the basis of the Malayan plantation experience.

4.52572 Malaya

Ali (1964) has reported favourably on the performance of A. hunsteinii in Malaya. In 1954 about half an acre (0.2 ha) was planted at the Forest Research Station, Kepong (450' (150 m) above sea level) using veneer-tubed seedlings averaging 5" (12.7 cm) in height and ten months from the sowing (much smaller and younger than in New Guinea). 165 seedlings were planted at 12' x 9' (4 m x 3 m) spacing; the soil type was moderately heavy granite-derived clay loams on a well-drained hillside. The area was formerly under vegetable garden prior to reservation and re-colonisation by secondary species some 25 years before planting. One year after planting the secondary re-growth was gradually opened up by poison-girdling. 90% survival was achieved one year after planting with average and dominant heights of 15" and 28" (38 cm and 71 cm) respectively.

4.526 Tending

As for A. angustifolia

4.527 Cost of Establishment

While it is realised that the cost of establishment in various regions may not be comparable for a variety of reasons, it is thought useful to indicate here the cost of establishment of A. hunsteinii in New Guinea at 1957-58 level of labour prices/costs.

Operation	Mandays
Clearing	14
Burning and preparation	4
Stacking and burning	4-12 *
Planting	7
Tending first year	15-20 *
Subsequent tending (yrly.)	12 (spot) 3 times
Total cost up to but excluding first thinning	54-67

* Cost of these operations varies with weather conditions and average labour cost was 6/-d per manday in New Guinea in 1957-58.

At the 1957-58 labour costs the establishment cost per acre was about £16 - £20, excluding overheads and the cost of plants.

4.528 Pruning

This depends on the object of management. For example in Queensland, Australia, where wood quality is an objective in pruning, the main aim is to minimize the knotty core in selected stems to be retained to an age when the cost of pruning will be recouped from the increased value of clear wood produced (Robinson, 1965). Again in Queensland the maximum pruning height is 21 ft. (6.4 m) achieved in stages and the prescriptions for A. cunninghamii were framed originally to meet the demand of the plywood industry based on A. cunninghamii for clear peeler logs in multiples of 6'6" (2 m) length; pruning has also been found to increase the value of saw-logs.

It has been found that about 40% of the total height of a stem can be pruned without significant effect on height or girth measurement (Robinson, 1965). Above this limit, girth increment is reduced but height growth is unaffected until 60% level is reached. Pruning to 60% of total height is considered the upper practicable limit if suppression is to be avoided and it has been found that pruning of A. cunninghamii stems causes an average loss of about 1.5" (3.8 cm) in girth increment at breast height during the pruning period and the following two years, but subsequent basal area increment is not affected. Whatever may be the objective of pruning in practice its cost will have to be related to anticipated price levels (stumpage values) for the product.

With the above general remarks about Hoop Pine in mind, the pruning prescription which has been established for A. cunninghamii in Australia will serve as a guide in areas where A. hunsteinii may be introduced.

(i) The first pruning is made when the canopy closure is complete and when 75% of the stand exceeds 20 ft. (6 m) in height.

(ii) In the first pruning all stems selected for pruning are to be pruned as high as can be reached from the ground with pruning saw and limbs cut as close to the trunk as possible. High pruning is to a height not greater than 25' (7.6 m) from the ground when 75% of the stand exceed 45' (13.6 m).

(iii) In marking for high pruning the number of trees left per acre is between 120 and 160 (264-352 per ha) and only trees of good form, which are dominant or co-dominant trees are marked for pruning.

4.529 Thinning

The following tentative thinning schedule used in New Guinea may be followed as a guide. But each new area will have to work out a schedule acceptable to it. In New Guinea since pruning is selective the first thinning is at the time of pruning.

Predominant height		No. of trees to be retained	
Feet	Metres	Per acre	Per hectare
50	15.24	350	865
60	18.3	250	618
70 plus	21.3	170	420

Thinning aims at the removal of stems in the following order:

(i) suppressed and useless trees

(ii) dominant and co-dominant stems of poor form, particularly where such stems are competing with select stems.

(iii) double and multiple leader stems

It is the practice in New Guinea to coat all stumps and wounds of the remaining stems with creosote to avoid fungal entry, especially by species of Fomes.

4.5291 Thinning Intensity

This would also have to be determined for each particular area.

In New Guinea it has been laid down that a stand should not be reduced below 350 effective stems per acre at the time of the first thinning. An 'effective stem' is one which is defined as 'one which has a diameter over bark of 4" (10 cm) in a stand whose predominant height ranges from 45' to 55' (13.6 m to 16 m).' On this basis the following limits have been adopted in New Guinea:

Height		Diameter over bark at breast height	
Feet	Metres	Inches	Cm
45/55	13.6/16	4	10
55/65	16.0/19.7	5	12.7
65 plus	19.7	6	15

As in the case of pruning and thinning intensities each region would have to work out its own 'effective stem' and'effective limit'.

4.6 Mensuration

4.61 New Guinea

Information on growth data of plantation-grown A. hunsteinii from New Guinea is at present very limited because only small areas have reached sufficient age for yield plots establishment (White, 1968). However, there are indications that early development of A. hunsteinii is very encouraging as the data on page 68from yield plots in New Guinea shows. (See page 74)

4.62 The Malayan table below shows an enumeration result from the eighth year (in girth classes) at which time a thinning to favour the more vigorous stems had removed 36 trees of 5.72 square feet (0.52 m^2) basal area.

No. per girth classes breast height o.b. ins. (cms) — Basal Area

Age	No. of trees	0-30.5 cms (0-12 ins)	30.5-45.7 cms (12-18 ins)	45.7-61 cms (18-24 ins)	61-76 cms (24-30 ins)	76-91 cms (30-36 ins)	m^2 (sq. ft.)
8	80	4	27	43	6	-	1.50 (16.37 sq. ft.)
9	80	1	11	43	24	1	2.022 (21.98 sq. ft.)
10	80	1	2	26	43	8	

4.61

Data from Yield Plots (New Guinea)

Plot No.	Age (yrs.)	No. trees per acre	per ha	Predominant ht.* ft.	(m)	Mean diam. (o.b.) ins.	(cm)	Basal area per acre	per ha	B.A. C.A.I.
5	8.5	234	(578)	41	(12.5)	5.6	(14.2)	45.6	(10.5)	11.2
6	8.5	332	(820)	45	(13.7)	5.4	(13.7)	60.1	(13.8)	13.0
4	12.5	206	(509)	67	(20.4)	9.2	(23.3)	107.7	(24.7)	11.4
3	13.5	316	(781)	77	(23.5)	8.7	(22.0)	140.8	(32.3)	12.3
2	16.5	136	(336)	93	(28.4)	13.6	(34.5)	126.6	(29.0)	6.8
7	16.5	290	(716)	90	(27.4)	9.9	(25.1)	165.8	(38.0)	10.0

* Mean height of the tallest 20 trees per acre (49 per ha.)

White points out that thinning has been very variable from plot to plot and that cultural history has markedly influenced diameter growth. For example in plot 2 above the trees were reduced by 40 per acre (99 per ha.) in 1966. White thinks that an improvement could be expected in C.A.I. of the basal area at the next measurement.

The report added that at the last measurement, the top height (i.e. the average height of the dominant trees in the stand) averaged sixty feet (20 m) and that the whole crop appeared vigorously healthy and comparable to plantations in New Guinea.

4.7 Protection

4.71 Fire

A. hunsteinii is very susceptible to fire and care should be taken to exclude fire from the plantations throughout the rotation. This means that a system of external and internal fire breaks should be designed and surveyed well in advance of planting.

4.72 Birds

These can cause considerable damage. For example, in New Guinea, the cockatoos have been found to damage the seed crop of both A. hunsteinii and A. cunninghamii.

4.73 Insects

4.731 Termites

Termite damage in Malaya and New Guinea may be serious. One species of termite not found in Africa or America has been isolated and identified in New Guinea as Coptotermes hyalopex or C. elisae. This termite attacks young trees, entering the bole through galleries made in the root and completely removes the core of the stem. The attack can be controlled by the use of Aldrin and Dieldrin. Similar damage has been done in the Malayan plots planted in 1955 but deaths are not widespread.

4.732 Hylurdrectonus araucariae Schedl.

This small Scolytid leaf miner attacks A. hunsteinii in plantations when the trees are 10 to 12 years old in regions 1100 - 1350 metres above sea level. This insect is found also in natural stands. In plantations, attacked trees have been dug up and destroyed.

4.733 Miliona isodoxa

This moth is known to attack the leaves and twigs of Araucaria and the larvae cause serious damage to the leaves on which they feed.

4.734 Other Insect Pests

Experience in New Guinea has shown that white grubs, mole crickets and cutworms become troublesome in some nursery beds following the addition of sawdust. Control may be effected by spraying the bed with one gallon (4.5 litres) of 1 lb. (0.45 kg) of Gammexane to 50 gallons (227 litres) of water solution. This may be repeated in a few days if control is not effected with the first spraying.

4.74 Fungi

4.741 Armillaria and Fomes

These fungi attack plantations from which hardwoods have been recently cleared. Morel (1967) gives the name of the latter fungus as Fomes noxius. Damage from Armillaria mellea has been most common where Parinari spp. are present.

4.742 Root Rot

A. hunsteinii seedlings may suffer from root rot two to four months after germination. Investigations showed that this rot was caused by soil inhabiting fungus and this fungus has been isolated as Fusarium sp. The first symptom of root rot is a change of colour of the leaves from dark green to yellow green. This is accompanied by loss of turgor and in later stages by longitudinal wrinkling of the leaves. At the same time the stem begins to shrink and when the seedling is lifted much of the cortical tissue is so damaged that it separates from the central root and remains in the ground. A pink slime of spores can be seen on decaying cortical tissues and in addition black masses of spores of a Pestalottia spp. are seen in dying foliage.

Root rot may occur between the age of 2-4 months, i.e. between the exhaustion of seed food reserves (cotyledons) and the commencement of vigorous independent growth. The attack is said to be intensified and become more serious when the supply of nitrogen is increased. However, the main conditions predisposing the seedlings to the disease are heavy soil texture and excessive moisture, resulting in inadequate aeration. The incidence of the disease can be minimized by chemical sterilization of the nursery soils and not by treatment of seeds with fungicides. A low carbon/nitrogen ratio (C/N ratio) of the soil increases and a high ratio decreases the occurrence of the disease. This high carbon/nitrogen ratio can be achieved by the addition of sawdust which is beneficial both in improving and increasing the carbon/nitrogen ratio. In Australia, however, root rot caused by Rhizoctonia crocorum is brought under control by use of the chestnut mixture described in para 3.752. This mixture is applied at the rate of 2 gals. per square yard (9.1 litres per 0.84 m^2) of bed on beds which contain plants and at the rate of 1 gal. to 1 square yard (4. 5 litres to 0. 84 m^2) on beds which do not contain plants.

4. 75 Chlorosis

The incidence of chlorosis was found to be quite common during the early period of nursery establishment in New Guinea. The symptoms were observed to be a yellowing of the foliage resulting from chlorophyll deficiency. The terminal leaves of A. hunsteinii become uniformly yellow, tending towards whiteness, while the lower leaves remain green. A. cunninghamii seedlings exhibit similar symptoms, but appear to be a little less susceptible to chlorosis than A. hunsteinii. This is followed by a marked depression of growth and the development of short, stubby and poorly ramified roots below ground level. As a secondary effect butt rot of the chlorotic terminal shoots often follows.

Chlorosis was found to be due to a lime-induced iron deficiency occurring in soils of high pH and the resultant non-availability of mobile iron. This arises out of the excessive alkalinity of the soil, usually where the pH of the soil is above 7. 6. Chlorosis can be reduced by the application of ground sulphur at the rate of 15 lbs (6. 8 kg) per 200 sq. ft. (18. 5 m^2) and allowing six weeks between the addition of sulphur before sowing or the addition of organic material. The improvement is due to increasing the acidity of the soil. Basden (1960) suggested that where there is a choice of soils for nurseries and reforestation, those which are alkaline should be avoided.

5. 0 OTHER ARAUCARIA SPECIES

The following Araucaria species are also being grown for timber or for ornamental value.

5. 1 Araucaria bidwillii Hook

5. 11 Local Name

Bunya Pine

5. 12 Distribution

Bunya Pine has a much more restricted distribution than Hoop Pine. It occurs in southeast coastal Queensland between Gympie and the Bunya mountains west of Yarraman and there is a small isolated occurrence about 25 miles (40. 23 km) inland from Port Douglas at latitude 16. 5°S. Its altitudinal range is from 500' to 3500' (152. 4 m to 1066.4 m) above sea level. (See map at para 3.1)

5.13 The Tree

Bunya Pine is a large tree with dimensions slightly less than those of Hoop Pine, being 100' - 140' (30.48 m - 42.67 m) in height and 2' - 3' (0.61 - 0.91 m) in diameter. The mature tree has a straight cylindrical bole clear of branches for half to two-thirds of the total height. The main stem is persistent to the top of the crown. But at old age the crown tends to flatten and the branches become crowded together near the tip of the tree.

A full description of the tree (Anon, 1957) is given below:

Bark: Persistent over the whole of the trunk to the small branches. Hard and rough, cracked into thin horizontal scales 1" - 3" x 0.3" - 1" (2.54 - 7.62 cm x 0.76 - 2.54 cm). Dark brown to black on the surface, red grading to orange when cut and very thick.

Leaves:
(i) Seedlings: spirally arranged, spreading from the stem, linear, triangular in section, 0.4" - 0.8" (1 - 2 cm) long, straight and sharply pointed.
(ii) Adult: spirally arranged, but two-ranked through twisting of the leaf bases, without stalk or very shortly stalked, lanceolate, sharply pointed and hard, glossy dark green above, slightly paler and duller below, measuring 0.7" - 2" x 0.2" - 0.4" (1.78 cm - 5 cm x 0.5 cm - 1 cm).

Flower: Male and female flowers are found on separate trees or sometimes on the same tree. Male catkin is long and narrow, up to 8" x 0.5" (20.32 x 1.27 cm) at the ends of short lateral branchlets; formed of crowded scales, spirally arranged, each with a diamond-shaped expanded summit, covering about 12 pollen cells. Female cones are formed by numerous bracts, spirally arranged at the ends of short branchlets. Each scale has a sharply pointed projection at the tip and a single ovule attached to the upper surface.

Fruit: Ovoid cones, up to 12" x 8" (30.48 x 20.32 cm), the scales are woody expanded laterally and up to 3" (7.62 cm) broad, with a single ovoid seed about 2" x 1" (5 cm x 2.54 cm).

5.14 Habitat Conditions

5.141 Climate

5.1411 Rainfall

Bunya Pine is a species of sub-tropical climate with warm humid summers. In its native habitat annual rainfall is mainly 35" - 50" (889 mm - 1270 mm) with more than half falling in the period November to March.

5.1412 Temperature

Its temperature requirements are similar to those of Hoop Pine (para 3.312) in the districts where both species grow in Queensland although Bunya Pine occupies the lower and moister positions.

5.1413 Frost

Bunya Pine is more frost hardy than Hoop Pine. At its lower altitudes frosty days are unknown or are only few in number, but at higher elevations there may be up to 30 a year. On the ability of Bunya Pine to resist frost, Cromer (1939) has found that it is entirely unaffected by temperatures as low as $23^{o}F$ ($-5^{o}C$) and has a critical temperature below $21^{o}F$ ($-6.1^{o}C$).

5.142 Edaphic Factors

Bunya Pine is most common on rich soils, especially those of volcanic origin, but it will grow on poorer soils if moisture conditions are suitable and adequate.

5.143 Physiographic Factors

It is a species of the coastal ranges, preferring moist valley bottoms at lower altitudes, but spreading onto hill and mountain slopes at higher elevations.

5.144 Ecological Association

Bunya Pine never forms pure stands but it is found scattered as a predominant species over rainforests. It grows in the same locality as Hoop Pine, but is is found in the lower and moister areas while Hoop Pine prefers the higher and better drained sites.

5.145 Biotic Considerations

The fruit is large and football-like and contains edible nuts which are relished by the Australian aborigines, white men and wallabies alike.

5.15 Nursery Procedure and Plantation Establishment

Both the nursery procedure and the technique of plantation establishment are similar to those of Hoop Pine (see paras 3.523 and 3.524). But in Queensland (Australia) afforestation programme it has been used to a lesser extent than Hoop Pine because it grows more slowly, is more heavily branched, and it is more difficult to establish than Hoop Pine.

On the problem of establishment it is useful to record Smith's (1946) observations on the germination of A. bidwilli. Writing in the American Naturalist he said: "In August, 1939, cones (of A. bidwilli) were received and several of the large seeds were planted. The seeds germinated readily, but no true leaves appeared even after several months.

The cotyledons are surrounded by a large source of food which apparently can nourish the young plant for months while its root system is becoming established. The seed upon germination develops an enlarged fusiform radicle from which the true leaves are later grown. The seed and the fusiform radicle show an intermediate plant tissue which soon decays away, leaving the remains of the old seed separated from the nearly established plant.

Three germinated seeds were accidentally broken off from the fusiform radicle when being examined, but this did not affect the young plants adversely, since they all grew and developed true leaves and much sooner than three other seedlings with the seed attached. These seedlings with the seeds attached developed a root system, but the seed shells were still in place one year after planting, were empty and probably had been for some time. Within the seed shells that were still in place, plant growth of 1" to 2" (2.54 cm to 5 cm) had taken place. This growth had rudimentary leaves, while the three plants from which the seed were broken were well branched, leafy and about 8" (20.32 cm) in height."

In Queensland it has been observed too that the seed of A. bidwilli upon germination transfers its food reserve to the radicel and this probably accounts for the enlarged fusiform radicle referred to by Smith.

5.16 Tending, Pruning and Thinning

See paras 3.5244, 3.5247 and 3.5248.

5.17 Future Possibilities

Bunya Pine has been tried in several countries either as an ornamental tree or on an experimental scale with a view to commercial growing if the results justify it. It has been tried in Fiji, India, Kenya, Malaya, Solomon Islands, Trinidad and Tobago, Uganda and the Union of South Africa (Streets op. cit).

5.2 Araucaria excelsa R. Brown
(Syn. A. heterophylla (Salisbury) Franco)

5.21 Local Name

Norfolk Island Pine

5.22 Distribution

Araucaria excelsa is a native of Norfolk Island (a small, low and windswept island in the Pacific Ocean, longitude 167^{o}N and latitude $28\frac{1}{2}^{o}$). It is also found naturally in Hawaii. But it has spread all over the world as an ornamental tree species (Streets op. cit). In the Philippines it has been widely planted as ornamental and as Christmas trees and has been used for landscape planting in residential areas (Marin, 1961 and Caleda, 1964). A. excelsa is most nearly allied to A. columnaris, but differs from it in its more plumose habit and coarser foliage (Dallimore and Jackson, op. cit).

5.23 The Tree

Norfolk Island Pine is a large and beautiful tree which under natural conditions attains a height of 150' - 200' (45.72 m - 61.0 m) and a diameter of 5' - 7' (1.52 m - 2.13 m). Dallimore and Jackson (op. cit) have described the tree as follows:-

Main branches:	Horizontal, in regular whorls with lateral branchlets horizontal or pendant.
Bark:	The outer bark peels off in thin flakes.
Leaves: (two kinds)	(i) Those on juvenile or lateral branchlets are soft, awl-like, incurved, bright green and up to 0.5" (1.27 cm) long. (ii) Those on older and fertile shoots are dense, overlapping, broadly ovate, up to 0.25" (0.63 cm) long and 0.2" - 0.25" (0.5 cm - 0.63 cm) wide at base, with an incurved horny point.

Cones: Often broader than long, 3" - 4" by 3.5" - 4.5" (7.62 cm - 10.16 cm by 8.89 cm - 11.43 cm)

Seed: 1" - 1.12" (2.54 - 2.84 cm) long and 0.5" (1.27 cm) wide, exclusive of well-developed wings. The apex of each scale is a soft, flat triangular spine 0.4" - 0.5" (1 cm - 1.27 cm) long and less than 0.25" (0.63 cm) wide at base.

Several forms of *A. excelsa* are known but they do not appear to be very distinct.

5.24 Edaphic and Physiographic Factors

A. excelsa appears to thrive well in all types of soil and in the Philippines it has been found to grow well on low and high elevations, up to 5000' (1524 m) where the climate is generally cool.

5.25 Nursery Procedure

There is very little published information on the nursery procedure and plantation techniques for establishing *A. excelsa*. Propagation is, however, either by seed or by vegetative means such as cuttings (with or without growth inducing chemical substances).

5.251 Cuttings

A. excelsa can be established by the use of terminal bud cuttings. In a series of experiments with cuttings (Marin, op. cit) has shown that (with respect to Philippines) *A. excelsa* cuttings can be rooted with or without growth inducing substances, that indolebutyric acid and rootone gave better results than alphanaphthalene-acetic acid as growth inducing chemicals, that seedlings of *A. excelsa* can sprout or coppice after the removal of the terminal buds, that rooting is best secured when the cuttings are short, from 5 cm - 20 cm long and under Philippine conditions the percentage of rooting and the emergence of sprouts is higher in October (rainy season) than in the dry season and finally that the addition of ammonium sulphate increases the number and growth of sprouts on mother plants.

5.252 Propagation by Seed

5.2521 Seed Storage

The seed is large and under ordinary conditions it quickly loses viability. Akamine (1946) has shown that the optimum storage temperature to prolong the viability of the seed is about 7°C (44.6°F) under a relative humidity of 60% to 75%

5.2522 Seedlings

Norfolk Island Pine seedlings are very difficult to raise in the nursery from seed. In the Philippines the seedlings are brought by plane or boat from Hawaii, bare-rooted and packed in sphagnum moss. The care of these seedlings has been described by Jacalne (1951) as follows:

On arrival each seedling is potted in tin cans filled with a mixture of top soil and leaf mould in the proportion of 4 to 1. These plants are later kept under the shade for four months and watering is done as often as it is necessary to keep the soil from drying. During these four months the plants attain only an average height growth of 2 cm. At the end of this period the plants with the pots are set in transplant beds where they are exposed to the light during part of the day. In one year of growth the plants attain only an average of 20 cm in height. At this time the tin cans are removed around the roots of the plants and the plants are set out in other transplant beds where they receive full sunlight during most part of the day. One month after transplanting a teaspoonful of ammonium sulphate is added to each plant to quicken growth. This is repeated once in every two months for a period of eight months and under these conditions the plants have been found to attain a total height of between 0.75 m - 1.30 m in two years. Thus in about 3.5 years the plant will attain a height of barely 1 m. After this period, however, the plants begin to grow at a more rapid rate.

5.26 Plantation Establishment

Subsequent care of the seedlings will depend on the size and condition of the plants. In some cases plants are rooted either in tin cans or in earthen pots or lifted with a ball of earth around the roots of the plants. In planting,a hole, sufficient to contain the ball of earth, should be made and additional top soil added all around and below the root system to provide more plant nutrients necessary for further growth. (No mention is made of root-wrenching). The plants require shade for about one week after planting to reduce the sudden exposure to sunlight and after that they are very intolerant of shade and do not thrive under shade so that once they are fully established they must be given full sunlight.

Norfolk Island Pine is very wind firm and can withstand salt sprays very effectively. It has been grown along the Goldcoast beach, south of Brisbane, Australia, in salty conditions with success.

5. 27 Tending

See para 3. 5244

5. 28 Countries where A. excelsa has been tried and future possibilities

5. 281 Countries

It has been grown in Victoria and Queensland in Australia where it is regarded as naturalized (Streets, op. cit). Other places include Cyprus, Fiji, Kenya, New Zealand, Palestine, Southern Rhodesia, Trinidad, Uganda, Union of South Africa where a plantation had a mean height of 60' (18. 29 m) and a diameter of 7. 6" (19. 3 cm) at 18 years of age, with a stocking of 500 stems per acre (1235 per ha) on a moderately deep loam with 59" (1498. 6 mm) of rain per year at 1700' (518 m) above sea level and subject to light frosts (Streets op. cit). It has been tried in Zanzibar where a few trees established in a coral area have all died after attaining heights over 70' (21. 23 m) in about 50 to 60 years.

5. 282 Future Possibilities

The great problems with this species is seed supply and short retention of viability. There has been very little success in germinating the seeds after storage because of its short viability.

5. 3 Araucaria balansae Brongniart and Grisebach

This species is a native of New Caledonia and it is said to resemble A. columnaris in certain characteristics. But it can be distinguished from A. columnaris by its smaller leaves and more slender growth (Dallimore and Jackson). These authors have described A. balansae as follows:

A tree 45' - 60' (13. 72 m - 18. 29 m) high, with horizontal branches and long, slender, pendant branchlets.

Leaves: Small, uniform in size, densely crowded on the branchlets and lasting many years. Each leaf measures about 0. 12" (0. 31 cm) long and almost as wide at the base, curving inwards and appearing to clasp the stem. The stomata are found on the inner surface.

Male catkins: These measure 2" - 3" (5.08 cm - 7.62 cm) long, 0.75" - 1" (1.9 cm - 2.54 cm) wide.

Cones: Oval, terminating short shoots, 2.5" - 3" (6.35 cm - 7.62 cm) long by 2" - 2.5" (5.08 cm - 6.35 cm) wide, the scales ending in stiff, lance-shaped bristles 0.33" (0.84 cm) long.

A. balansae has no economic importance as a timber tree, but on account of its decorative character, it is grown in greenhouses in most European countries, for example it may be seen in the Temperate House at Kew, London (Dallimore and Jackson, op. cit).

5.4 Araucaria beccarii Warburg
Araucaria cunninghamii Beccari (not Sweet); A. cunninghamii var papuana

A. beccarii is found in New Guinea and on the Arfak Mountains in N. W. Dutch New Guinea. Dallimore and Jackson describe it as "a handsome tree, 70' - 80' (21.34 m - 24.38 m) high". It is said to resemble or be allied to A. cunninghamii but differing in its less symmetrical branching and the absence of the candelabra-like habit peculiar to A. cunninghamii. The leaves of mature trees are about 0.4" (1.02 cm) long, and about 0.1" (0.25 cm) wide at base, the apex sharp-pointed and reflexed. The cones are said to be much larger than those of Hoop Pine and the cone-scales longer, with a narrower base and more pointed apex (Dallimore and Jackson).

There is no information on whether this species has been introduced into cultivation anywhere, or an assessment of its economic potential.

5.5 A. columnaris (Forst.) Hook
(Syn. A. cookii R. Br.)

This is a large tree, up to 130' (39.62 m) in height and is found in New Caledonia (a small island situated in the Pacific Ocean between longitude 164^{o} - 167.5^{o}S and latitude 20^{o} - 22.5^{o}), Polynesia and the Isle of Pines. It sheds its lower branches and replaces them with short shoots, thus producing the effect of a dense green column suddenly widening out at the top (Streets op. cit).

The wood has similar properties to those of A. excelsa (para 5.281) and A. cunninghamii (para 6.0 et seq.) but it does not appear to have any economic value outside its native country because it seldom grows straight and because of its habit of shedding its lower branches and replacing them with short epicormic shoots. However, it has been tried in some countries either as an ornamental or as a plantation tree. These countries include Australia (in Queensland) where the growth was reported to be slow, Kenya (in the Mugaga Arboretum), Mauritius (as an ornamental tree), Uganda and the Union of South Africa, where a plantation had a mean height of 105' (32 m) and a diameter of 21.7" (0.55 m) at 49 years of age, with a stocking of 67 stems per acre (165.5 stems per ha) and good form on a deep fine soil with 45" (1143 mm) of rain per annum, at an altitude of 200' (61 m) with a westerly aspect and no frosts (Streets op. cit). It withstood the 1960 cyclone in Mauritius as well as any other exotic tree and regrew the branches shed during the hurricane from epicormic shoots (see 3.712).

5.6 Araucaria muelleri Brongniart and Grisebach

Dallimore and Jackson (op. cit) describe the A. muelleri as a rare tree from New Caledonia. Leaves are thick and leathery, measuring 1" - 1.25" (2.54 cm - 3.17 cm) long and 0.5" - 0.62" (1.27 cm - 1.6 cm) wide, ovate, closely overlapping and sharp-pointed, with the stomata on each surface. The male catkins are said to be terminal, up to 10" (25.5 cm) long and 1.5" (3.61 cm) wide. The cone is ovoid, 4.5" - 6" (11.43 cm - 15.24 cm) long and 3.5" - 4" (8.89 cm - 10.16 cm) wide. It resembles a small cone of A. araucana and the base is closely clasped by the leaves. The seed is about 1" (2.54 cm) long and 0.33" (0.84 cm) wide, with narrow flimsy wings.

A. muelleri is said to be most closely related to Araucaria rulei but differs from it by its larger and coarser leaves. It is separated from A. araucana by shorter leaves and longer male catkins. There is no reference to its growth dimensions under natural conditions and it does not seem to have any economic importance as a timber tree.

5.7 Araucaria rulei Ferdinand von Mueller
A. Niepratschki Baumann ex Pynaert; A. Van Gaertii Hort.

A. rulei is also a native of New Caledonia. It is a small to medium sized tree, reaching 50' (15.24 m) in height and clothed with branches spreading on all sides of the trunk to a distance of 15' (4.57 m) (Dallimore and Jackson). The branchlets are pendulous, tail-like and measure up to 1.25" (3.17 cm) in diameter.

The leaves are dark green, glossy, incurved, closely overlapping and clasping the stem. The leaves are also stiff, hard, leathery and very variable in length on different plants, often measuring 0.5" - 1" (1.27 cm - 2.54 cm) long and 0.25" - 0.33" (0.63 cm - 0.84 cm) wide at the base. The leaves are also short-pointed at the apex with very minute stomata on the upper surface only.

Male catkins are terminal, 2" (5.08 cm) long and 1" (2.54 cm) wide. The cones are said to be similar to those of A. columnaris with the apex of scale terminated by a spine-like growth 0.75 (1.9 cm) long. The seeds have narrow wings and they measure about 0.33" (0.84 cm) long and 0.19" (0.47 cm) wide.

Two varieties of A. rulei are known. There is A. rulei var Goldieana (T. Moore) Masters. It differs from A. rulei by its smaller leaves and neater habit. The other variety is A. rulei var intermedia and Dallimore and Jackson think that it is intermediate in foliage between A. rulei and A. columnaris and that these two varieties appear to connect A. rulei and A. columnaris, A. rulei being distinguished from A. columnaris by its larger and stiffer leaves.

A. rulei is of no economic importance as a timber tree, but it has been grown in the Union of South Africa where three trees were reported to be growing satisfactorily.

5.8 Araucaria araucana and little known species

Other species of Araucaria mentioned in para 1.22 are A. bernieri Buchholz, an inadequately known species allied to A. balansae and found near the headwaters of the Riviere des Pirogues, Plaine des Lacs, Southern New Caledonia; A. biramulata Buchholz, a tree 50' (15.24 m) high with rather pendulous and twisted branches, found in Plaine des Lacs, New Caledonia; A. humboldtensis, a little known tree 40' - 50' (12.19 - 15.24 m) high from New Caledonia and A. araucana (Molina) K. Koch., Chile Pine or Monkey Puzzle (syn. A. imbricata Pavon) the only one of economic importance. It is a tree of 50 - 150' (15.24 - 45.72 m) high, with a trunk of 3' - 5' (0.91 m - 1.52 m) in diameter. However it is a tree of the temperate zone, being confined to Southern Chile and Western Argentina and therefore outside the lowland tropics.

6.0 THE WOOD

6.1 General Properties

Because of the great similarity in the properties of all the Araucaria species this section covers data on all the important species. Araucaria wood is noted for its light colour, indistinct growth rings, uniform texture, straight grain, light to medium weight and ease of working. It seasons well but the presence of more compression wood, when grown under poor conditions, is a serious defect. The wood fibres are long and suitable for pulp and paper. The pulp is particularly suitable for blending with other pulps such as hardwood pulps to increase tearing strength. Araucaria pulp does not withstand prolonged beating.

Mechanical and strength properties of the wood are good, being better than wood from other trees of the same density. The wood can be put to a variety of uses from construction to packaging material.

6.2 Anatomy

The timbers of Araucaria and Agathis are very similar and there appears to be no certain way to distinguish between the timbers of the two genera (Jane, 1956). But both may be distinguished from other softwoods by the pitting on the walls of the vertical tracheids. Where multiseriate pitting occurs in wood of other conifers the arrangement of the pits is nearly always opposite; but alternate pitting is the rule in both Agathis and Araucaria, opposite pitting is rarely seen. The pits are commonly in 2 - 4 vertical rows. Jane (op. cit) has pointed out that in these two genera the pits may be so crowded that the normally circular outline becomes somewhat flattened and the pit border may become more or less hexagonal in surface view.

The timbers of Araucaria and Agathis are known for their regular growth, and even where growth rings are apparent there is generally little difference between early wood and late wood. Vertical tracheids have strikingly large diameters and the ray parenchyma cells have thin horizontal walls. The pitting in the rays is characteristically cupressoid, i.e. the pits are similar to those in the rays of Cupressus. (In this type of pitting the apertures in the earlywood are included within the limits of the border and are narrower than the border. Phillips (1948) has pointed out that this is characteristic of all members of Cupressaceae (except Thuja) and occurs also in a few Taxodiaceae (Taiwania and Taxodium), in Araucariaceae, Podocarpus spp., Taxus, and less regularly in Cedrus and Tsuga.)

Resin cells and resin canals are absent in these woods but resin is usually abundant in the ray cells and in the vertical tracheids. However, Agathis may be distinguished from Araucaria by its brownish heartwood, while that of Araucaria is in general pale or whitish; moreover while vertical tracheids of softwoods are often very long, extreme lengths have been recorded for Araucaria, for example, lengths of nearly 11 mm have been recorded for Hoop Pine (Jane op. cit).

6.3 Physical and Mechanical Properties

The physical properties of *Araucaria angustifolia*, *A. cunninghamii* and *A. hunsteinii* (syn *A. klinkii*) are summarized in the table on page 90 Sources of information are Johnston (1953), Gerry (1954), Jane (1956) and Anon (1957).

6.31 Mechanical/Strength Properties

A comparison of the mechanical properties of four Araucaria species (in the green condition)

PROPERTY (1)	UNIT (2)	PARANA PINE (3)	HOOP PINE (4)	BUNYA PINE (5)	KLINKI PINE (6)
Static bending - centre point loading:					
Modulus of rupture	lb/sq.in.	8690	6880	6290	6110
Modulus of elasticity	10^3lb/sq.in.	1570	1410	1320	1450
Compression parallel to the grain:					
Maximum crushing strength	lb/sq.in.	3820	3760	3200	3170
Modulus of elasticity	10^3lb.sq.in.	1950	1770	1630	1640
Shear parallel to grain:					
Maximum shear strength	lb/sq.in.	950*	858	720	670
Hardness:					
End	lb.	595	685	-	520
Izod:	ft.lb.	6.5+	6.8	4.6	6.2
Toughness:	in.lb.	103*	120	90	97

*Rebated sheer specimen

+Estimated values

Physical Properties of the Wood of Araucaria angustifolia, A.cunninghamii and A.hunsteinii

Species (1)	Colour (2)	Growth rings (3)	Rays (4)	Parenchyma (5)	Tracheids (6)	Resin ducts (7)	Grain (8)	Texture (9)	Odour (10)	Sp.gravity (11)	Density (12)
A.angustifolia	Pale brown to dark brown heartwood, red patches & streaks present; sapwood almost white or yellowish	Present but indistinct, the contrast between the final row of latewood tracheids and the succeeding rows of early wood tracheids not marked	Mainly uniseriate, horizontal walls of ray parenchyma thin; deposits present; ray tracheids absent	Absent	Bordered pits on radial walls of tracheids in 1-3 vertical rows present and indistinctive alternate arrangement, tending to hexagonal when crowded. Crossfield pits are cupressoid,2-8 per crossfield; Crassulae bars absent.	Absent but some resinous material may be included in the wood	Fairly straight	Very even and uniform	None	0.496 at 12% m.c., 0.513 based on oven dry volume & o.d. weight	Varies considerably 30-40 lb/cu.ft. Mean or average 33.7/cu.ft. at 12% moisture content
A.cunninghamii	Cream or almost white	As above or absent	As above 1-2 cells wide, no deposits	Absent or sparse	As above	Absent	Straight	Fine & even	None	0.521 at 12% moisture content	32.5 lb/cu.ft. at 12% moisture content
A.hunsteinii	Heartwood : attractive purplish cast that varies slightly in streaks. Sapwood: straw-coloured without the purplish cast	As above	As above	Absent	As above	Absent	Generally straight although spiral grain and some 'bird's eye' figure may occur	Even, compact and uniform	None	0.39(based on a weighted average of materials tested in Australia & the U.S.) or 0.452 at 12% moisture content	27 lb/cu.ft. at 12% moisture content

Parana Pine

The mechanical/strength properties of Araucaria angustifolia compare very favourably with other coniferous species of the same specific gravity range and, in some properties, may be classed with wood of greater density (Dohr, 1953). It is especially good in shearing strength, hardness and nail-holding capacity. But it is noticeably deficient in strength in compression across and perpendicular to the grain. It is rather brittle for structural purposes and much more so when compression wood is present.

Unlike most other species, Parana Pine shows greater strength in cleavage and tension perpendicular to the grain when broken tangentially to the annual rings than radially. Height hammer drop is reported to be good but the modulus of elasticity is low especially when compression wood is present.

Hoop Pine

In general the properties of Hoop Pine are very close to those of Parana Pine and for certain structural purposes both are equally suitable. Compression wood may also be found in Hoop Pine and could lead to the same structural defects noticed in Parana Pine. The ratio of strength to weight is high.

Klinki Pine

For general purposes Klinki Pine may be grouped with Hoop Pine in some strength properties, but it is inferior in most strength properties to Hoop and Parana Pines. Klinki Pine is a good substitute for Sitka Spruce in the aircraft industry and a comparison of the properties of Klinki Pine with those of Spruce shows that they are markedly similar (Kloot, 1957). Klinki Pine is superior to Spruce in all structural purposes except modulus of rigidity,* but it is slightly inferior to Spruce for use as a strut when the basis of comparison is strength/(specific gravity)^2 (Ryan, 1959). In the design of light aircraft the design stresses for Spruce may be used for Klinki Pine.

* Modulus of rigidity is defined as the ratio of the intensity of the shear stress across the section of a material to the shear strain, i.e. to the angle of distortion in radians. It is measured in pounds or tons per square inch.

6.32 Other Araucaria Species

Bunya Pine

The wood properties of Bunya Pine are in many respects similar to those of Hoop Pine. The wood is straight grained and even textured but in weight Bunya Pine is lighter than Hoop Pine, having an average density of 28.7 lb/cu.ft. (448.56 kgs per m^3) at 12 percent moisture content.

Norfolk Island Pine

The timber of A. excelsa is as good as those of other Araucarias described above. It has been classified as moderately heavy and its mechanical properties are those expected from species of its density/ specific gravity (Gerhards, 1967). The wood is stiff, moderately strong in both bending and compression strengths. Its density and mechanical properties are more or less comparable with those of Douglas fir. But the presence of spiral grain is a serious defect. Gerhards has investigated both the physical and mechanical properties of A. excelsa grown in Hawaii and gives the following figures for the more important properties:

Average specific gravity: *	
green	0.42
air-dry	0.44
Average static bending, air-dry:	
Modulus of rupture lb/sq. in.	10,500
Modulus of elasticity 10^3lb/sq. in.	1,540
Average compression parallel to grain:	
Maximum crushing strength lb/sq. in.	5,790
Modulus of elasticity 10^3lb/sq. in	1,710
Maximum shear strength parallel to grain lb/sq. in.	1,470
Shrinkage - green to oven-dry (%)	
Radial	3.5
Tangential	5.3
Longitudinal	0.27
Volumetric	8.9

* Based on volume at test and ovendry weight

6.33

A comparison of the mechanical properties of four Araucaria species

(Means quoted at 12% moisture content)

PROPERTY	UNIT	PARANA PINE	HOOP PINE	BUNYA PINE	KLINKI PINE
Air dry density	lb/cu.ft.	33.7	32.5	28.7	28.2
Static bending - centre point loading: Modulus of rupture	lb/sq.in.	13,830	13,100	12,270	11,100
Compression parallel to grain: Maximum crushing strength	lb/sq.in.	6,900	7,060	6,570	6,370

6.34 Comparison of strength/weight ratios

Air dry Sp.gr.at 12% m.c. (G)		0.540	0.521	0.460	0.452
Modulus of rupture/G	lb/sq.in.	25,610	25,140	26,670	24,560
Maximum crushing strength	lb/sq.in.	12,780	13,550	14,280	14,090

6.4 Seasoning and Shrinkage

6.41 Parana Pine

Warping and splitting of kiln dried Parana Pine is a principal defect. Warping is caused by the presence of compression wood as revealed through microscopical examination of samples. (Compression wood is an abnormal type of wood structure with intrinsically large shrinkage along the grain). Even some air-dried boards have been observed to warp (Pillow, 1951). The shrinkage values for green - ovendry Parana Pine are given in para 6.411.

6.411 Shrinkage Green to 12% moisture content

	Radial %	Tangential %
Parana Pine *	4.0	7.9
Hoop Pine	2.5	3.8
Klinki Pine	2.2	4.0

* Based on green to oven-dry

6.412 Kiln Drying

Kiln drying by accelerated schedules as well as at moderate temperatures has been recommended by Pillow (1951) and the schedules are given on page 95.

6.415 Kiln Drying Schedule D

For schedules designed for use with timber up to about 1½" (3.81 cm) thick dried in a forced draught kiln, the following schedules have been recommended by the Forest Products Laboratory (Princes Risborough, U.K.) for drying Parana Pine.

Moisture Content (%) of the wettest timber on the air-inlet side at which changes are to be made	Temperature (Dry Bulb)		Temperature (Wet Bulb)		Relative Humidity
	°F	°C	°F	°C	% (approx.)
Green	105	40.5	101	38.0	85
60	105	40.5	99	37.0	80
40	105	40.5	96	35.5	70
35	110	43.5	97	36.0	60
30	115	46.0	97	36.0	50
25	125	51.5	101	38.0	40
20	140	60.0	105	40.5	30
15	150	65.5	112	44.5	30

6.42 Hoop Pine - Seasoning and Shrinkage

Hoop Pine seasons well and no difficulties are encountered in air-drying or in kiln-drying in thicknesses up to 2" (5.0 cm), but in greater thicknesses some care must be taken to obtain satisfactory results (Anon, 1946). Hoop Pine may contain compression wood and this tends to cause warping in small sizes, but this can be eliminated by careful selection.

Shrinkage values for Hoop Pine are comparatively low. On the average they come very close to those of Klinki Pine and in drying from the green condition to 12 percent moisture content, Hoop Pine shrinks 3.8 percent in a tangential direction (backsawn) and 2.5 percent in a radial direction (quartersawn).

6.413 Schedule commonly used for commercial drying of Parana Pine lumber

Moisture Content		Dry Bulb		Wet Bulb		Relative Humidity
From %	To %	°F	°C	°F	°C	%
45	40	140	60.0	132	55.5	80
40	30	145	62.7	135	57.2	75
30	25	150	65.5	137	58.3	70
25	20	155	68.3	136	57.7	60
20	15	160	71.1	135	57.2	50
15	10	165	73.8	127	52.7	35
10	Final	170	76.6	116	46.6	20

6.414 Accelerated schedules suggested by the Forest Products Laboratory (Madison,Wisconsin) for 1-in. and 2-in. (2.54 cm and 5.0 cm) green and air-dried stock

Moisture Content		Dry Bulb		Wet Bulb 1-in. (2.54 cm) lumber		Wet Bulb 2-in. (5.0 cm) lumber		Relative Humidity 1-in. (2.54 cm) lumber	Relative Humidity 2-in. (5.0 cm) lumber
From %	To %	°F	°C	°F	°C	°F	°C	%	%
				For green stock					
Initial	40	180	82.2	170	76.6	173	78.3	79	85
40	35	180	82.2	166	74.4	170	76.6	72	79
35	30	180	82.2	160	71.1	165	73.4	62	70
30	25	190	87.7	155	68.3	165	73.4	43	56
25	20	190	87.7	140	60.0	150	65.5	28	37
20	15	200	93.3	150	65.5	150	65.5	30	30
15	Final	200	93.3	150	65.5	150	65.5	30	30
				For air-dry stock					
Initial	30	180	82.2	170	76.6	173	78.3	79	85
30	25	190	87.7	176	80.0	180	82.2	73	80
25	20	190	87.7	170	76.6	175	79.4	63	71
20	15	200	93.3	165	73.8	175	79.4	44	57
15	10	200	93.3	150	65.5	160	71.1	30	39
10	Final	200	93.3	150	65.5	150	65.5	30	30

6.421 Kiln Drying

Suitable kiln-drying schedules have been recommended for Hoop Pine and other Araucarias. These schedules are designed for use with timber up to 1½" (3.81 cm) thick dried in a forced draught kiln. It is pointed out that thicker dimensions require somewhat higher humidities to prevent severe moisture gradient developing and, further, when drying timber between 1½" and 3" (3.81 cm and 7.62 cm) thick the relative humidity should be 5 percent higher at each stage of the appropriate schedule, and 10 percent higher with wood greater than 3" (7.62 cm) in thickness.

Kiln-drying schedules for Hoop Pine as recommended by the Forest Products Research Laboratory, Princes Risborough, U.K. are given below:

6.422 Kiln Schedule J.

Moisture Content (%) of the wettest timber on the air-inlet side at which changes are to be made	Temperature (Dry Bulb)		Temperature (Dry Bulb)		Relative Humidity
	°F	°C	°F	°C	% (approx.)
Green	135	57	123	50.5	70
50	135	57	119	48	50
40	140	60	118	47.5	50
30	150	65.5	121	49	40
20	170	76.5	127	53	30

6.43 Klinki Pine - Seasoning and Shrinkage

6.431 Shrinkage

A. hunsteinii seasons well. Samples which were oven-dry at high temperatures showed no distortion, warping or any other form of degrade. Gerry (1954) has found the following shrinkage values:

			Range
Radial (green to oven)	average %	3.9	2.8 - 5.2
Longitudinal	average %	0.21	
Tangential to the growth rings (green to oven)	average %	6.3	
Volumetric	%	9.8	5.9 - 13.6

See para 6.411 for shrinkage values from green to 12 percent moisture content.

6.432 Kiln-drying Schedules for A. hunsteinii

Kauman and Campbell (1956) have found that A. hunsteinii could be dried easily without any significant degrade occurring in any thickness, even in wide backsawn faces. They concluded that the most outstanding feature of this species is its exceedingly rapid rate of drying, making it possible to kiln-dry 1 in. thick (2.54cm) stock from an average moisture content of 70 percent to 12 percent in approximately 27 hours and approximately 54 hours being required to kiln-dry 2 in. (5cm) thick stock over the same range. They recommended the following drying schedules for A. hunsteinii :

6.433

Size and Condition	Moisture Content Change Point	Dry-bulb Temp.		Wet-bulb Depression	
	%	°F	°C	°F	°C
1 in. & 1.1/4 in. (2.5 and 3 cm) thick green mixed sawn stock	Initial	180	82.2	30	- 1.1
	30 to final M.C.	180	82.2	50	10.0
	At final M.C. for two hours	200	93.3	5	- 15.0
1½ in. and 2 in. (3.8 and 5 cm) thick green mixed sawn stock	Initial	160	71.1	30	- 1.1
	30	180	82.2	30	- 1.1
	20 to final M.C.	180	82.2	40	4.4
	At final M.C. for four hours	200	93.3	5	- 15.0

In the case of backsawn boards in these thicknesses, where the risk of surface checking is somewhat greater, Kauman and Campbell recommended that the initial drying conditions be modified to a dry-bulb temperature of 160°F (71.1°C) with a wet-bulb depression of 20°F (- 6.6°C). When the stock has reached an average moisture content of 40% the appropriate schedule given in the table should be followed.

6.44 Bunya Pine - Seasoning and Shrinkage

No difficulty is encountered in kiln-drying Bunya Pine in thickness up to 2" (5 cm) but in greater thicknesses care must be taken to obtain satisfactory results (Anon, 1946). The same kiln-drying schedule may be used for both Bunya and Hoop Pines (see para 6.42). In drying from the green to 12 percent moisture content it shrinks 4.0% in a radial direction and 2.0% in a tangential direction.

6.5 Natural Durability and Preservation Treatment

All species of Araucaria have low resistance to decay. They are well adapted for interior use, but not resistant to either termite or fungal attack without preservative treatment. Moulds and other stains develop rapidly on untreated sapwood veneer exposed to 80 percent atmosphere humidity. The wood is easy to impregnate, both sapwood and heartwood.

6.6 Working and other General Characteristics

They are soft, very easy to cut and take smooth finish. Because of their softness and long fibres care is required in sanding. They have excellent dimensional stability because of their relatively low shrinkage.

They make excellent veneers for plywood and the plywood is well adapted for bending. They glue well and give a good finish with satiny lustre (McAdam, 1952). They take paint and varnishes well and uniformly; because of the colour of the heartwood they are well adapted to 'natural' finishes (Gerry, op. cit.).

6.7 Pulping Properties

6.71 Araucaria angustifolia

Parana Pine has some desirable pulping properties, particularly in respect of its exceptionally long fibres which range from 7 mm to 10 mm in length,and it is non-resinous wood . But the fibres are very thick and stiff which renders it unsuitable for certain types of paper. It may be used in mixture with other short-fibre coniferous or non-coniferous woods to increase tear strength.

No detailed study has been made on the pulping properties of plantation grown Parana Pine. In Brazil, wood normally used in the pulp industry comes from the virgin forests and such wood is said to be characterised by lack of uniformity. For instance the sapwood resembles Spruce-wood while there is an irregular reddish ring which surrounds the brown heartwood (Rys et al, 1952). When the specific gravity of such wood was determined the values for the sapwood and the heartwood varied from 0.45 to 0.56 and 0.48 to 0.60 respectively. Rys et al have determined the chemical composition of virgin grown Parana Pine and found the following chemical components:

6.711 Chemical Components of Parana Pinewood (Araucaria angustifolia)

	Sapwood %	Heartwood %
Solubility:		
in water	1.2	0.8
in ether	1.8	0.4
in alcohol-benzene	2.6	2.1
in 1% NaOH	10.2	11.6
Ash	0.4	1.4
Lignin	29.1	31.7
Pentosan	4.8	4.2
Cellulose	65.5	62.5

The chemical composition of any wood is important in assessing the desirable pulping properties.

The earlier studies on the pulping properties of Parana Pine have been made on old trees of 50-60 years. These trees usually have a red-brown heartwood with a specific gravity of 0.51 in the red centre and 0.59 in the dark middle layer (Rys, 1949). Both parts together comprise usually 65% of the wood volume; the outer layer has been found to be much clearer with a specific gravity of about 0.61. From the analysis of an 80 year old Parana Pine Rys (1949) obtained the following results:

	Inner Layer	Outer Layer
% Solubility in ether	0.73	1.47
% Solubility in water	0.65	5.15
% Ashes	0.10	1.57
% Cellulose	48	51
% Pentosan	10.75	

6.712 General Pulping Properties

Rys (1949) has drawn attention to the following points concerning the pulping properties of Parana Pine.

6.7121 Fabrication of Parana Pine pulp is made very difficult by the difference in specific gravity, between sap and heartwood. It is further complicated by irregular moisture distribution which was found to be 15%-20% higher in the outer layers than in the inner layer (heartwood).

6.7122 Sulphite pulp made from Parana Pine has thick fibres with a length up to 7 mm.

6.7123 Unbleached cellulose from old trees with a Sieber figure of 2.24 and a permanganate figure of 39 must be called difficult to bleach and the chlorine consumption of 8 percent is an additional factor. Rys found the following values at 43° Schopper Riegler:

Breaking Length	6400
Burst Factor	41
Tear Factor	1.48
Double Folds	650.0

These values were lower than those for European conifer pulps although the elongation (i.e. stretch - the total extension produced in a tensile test) was found to be equal to those of European conifer cellulose.

6.7124 The cellulose is easily bleached with a normal procedure giving a high whiteness. At 43° Schopper Riegler gave the following values:

Breaking Length	5100
Burst Factor	35
Tear Factor	115
Double Folds	320
Colour	85 bleached in one step with Ca-hypochlorite

6.7125 Kraft cellulose was found to give values below the European standard with the exception of elongation. At 43° Schopper Riegler and a permanganate figure of 80 the mean figures were:

Breaking Length	6800
Burst Factor	50
Tear Factor	226
Double Folds	700

The great length of the fibre and its big diameter constitute some drawbacks rather than advantages at the mechanical treatment, and regarding its chemical qualities Parana Pine sulphite cellulose is very low in resins and is chemically more sensitive than that from Spruce or Fir. Sensitivity against beating is also greater.

6.7126 Mechanical Pulp from Parana Pine

From old trees only the outer layers can be used for newsprint pulp and even this, if untreated, has only a brightness of 47-50 percent measured by the photovolt-reflectance meter. Rys expressed the view that an economically supportable bleaching can only bring a very small increase in whiteness. Because the fibres are long and stiff, they give a voluminous paper hard to be glazed.

The above views have been based on the pulping properties of old Parana Pine trees. Younger trees might give better results and an outstanding problem would be to determine the pulping properties of plantation grown Parana Pine as has been done for both Hoop and Klinki Pines (see para 6.72 et. seq.).

6.72 Hoop Pine

6.721 Preliminary Pulping of Hoop Pine

A preliminary pulping trial using a butt sample of plantation-grown A. cunninghamii has been made by Koeppen and Sitzman (1954) under the following conditions: temperature, 165°C (329°F); sulphidity, 33 percent; liquor:wood ratio, 5:1. The results obtained are shown below:

Preliminary Sulphate Pulping of A. cunninghamii
(All results are based on oven-dry wood and oven-dry pulp)

Cooking Conditions	Yield %	Lignin %	Yield of Furfural	Permanganate No.
20% total alkali as Na_2O, 3 hr. at 165°C(329°F)	48.0	6.2	6.0	37
20% " " " " 4 " "	47.5	5.7	6.1	29
20% " " " " 5 " "	46.0	5.2	5.5	26
22% " " " " 4 " "	45.0	4.0	5.3	24
24% " " " " 3 " "	45.0	4.6	5.5	23
24% " " " " 4 " "	44.1	3.7	5.2	19
24% " " " " 5 " "	42.8	3.5	4.8	18

6.722 Pulping of Plantation Grown and Virgin Growth Trees of Hoop Pine

Koeppen and Sitzman (op. cit) also investigated the pulping properties of both plantation-grown and virgin growth Hoop Pine. They examined pulps from (a) 12 butt samples, (b) a representative sample and (c) a composite sample under the following conditions: total alkali, 22 percent; sulphidity, 33 percent; liquor ratio 5:1; time 4 hours; temperature, 165°C (329°F.). The results obtained are shown on page 103.

Table 6.722 shows that pulps prepared from different trees had similar values for lignin and permanganate number. Table 6.723 shows the strength properties of the pulps. Pulps prepared from the composite sample had slightly better strength properties than those from the representative sample, but this difference was considered by the investigators to be of little practical importance. Table 6.722 again shows that the yield of pulps from the plantation grown trees was lower and the yield of furfural higher than those from the virgin growth trees. Yields from virgin growth trees were found to be similar to those normally obtained from some conifers of the temperate zone, while the yields from plantation grown trees were significantly lower. Further the investigators made a comparison of pulps prepared from virgin growth trees of A. cunninghamii and A. hunsteinii and found that both species gave sulphate pulps with nearly the same yield and strength properties.

6.73 Klinki Pine

6.731 Morphological Properties

Growth rings are indistinct or absent in both A. hunsteinii and A. cunninghamii. Both have long fibres compared to other softwoods. Gerry (1954) has recorded a minimum fibre length of 1.5mm and a maximum of 13.6mm with a mean of 6.3mm for A. hunsteinii. He also observed significant variations of fibre length within a tree and also between trees and concluded that such variations appear to be in general agreement with observations made in other species of both softwoods and hardwoods.

Average results of morphological studies of A. hunsteinii and A. cunninghamii are shown in the table on pages 105 and 106.

Koeppen and Sitzman found that measurements of fibre length were in general agreement with the findings of many other workers; that there was a regular increase in the fibre length from the centre of the tree outwards until a certain maximum was attained, after which the length remained constant; that the fibre length increased up to a certain height in the tree, after which it tended to decrease.

6.722

Sulphate pulping of A.cunninghamii
(Koeppen and Sitzman,1954)

(All results are based on oven-dry wood and oven-dry pulp)

Trees (1)		Tree No. (2)	Yield % (3)	Lignin % (4)	Yield of furfural % (5)	Permanganate No.(6)	Fibre length	
							Average length of whole fibres mm	Average length of total fibrous material mm
Plantation-grown trees	Butt samples	1	44.3	4.4	6.0	26		
		2	44.7	4.8	5.2	27		
		3	45.0	4.4	5.1	26		
		4	45.0	4.0	5.3	24		
		5	45.2	4.5	4.8	23		
		6	45.1	4.0	4.9	25		
		7	44.2	4.8	5.1	25		
		8	44.0	4.4	5.1	25		
	Repr. sample		45.4	4.4	4.9	24		
	Composite sample		44.3	3.7	5.0	23		
Virgin growth trees	Butt samples	2	47.7	4.2	3.4	23	5.74	4.13
		3	49.8	3.8	3.7	22	5.58	3.90
		6	49.6	4.0	3.6	23	5.67	4.34
		9	50.0	4.0	3.8	24	5.29	4.70
Average values for fibre length							5.57	4.26

6.723 Pulp evaluation tests of sulphate pulps prepared from Plantation-grown and Virgin growth trees of A.cunninghamii

Trees (1)	Tree No. g.b.h. (unbarked) (2)	Beating rev. (3)	Bulk (4)	Burst factor (5)	Stretch % (6)	Breaking length km (7)	Tear factor (8)	Air resistance sec. (9)	Folding endurance M.I.T. x/ (10)	Freeness C.s.f. +/ (11)	Drainage time sec. (12)
Virgin growth trees		1,125	1.56	83	5.4	8.9	261	6	6,300	706	6
	2	4,500	1.48	94	6.2	10.4	163	5	4,900	693	5
	20.75" (0.53 m)	9,000	1.42	102	6.1	11.5	149	9	3,700	656	6
		18,000	1.37	116	5.2	11.1	105	35	3,000	490	5
		1,125	1.61	54	5.4	7.0	258	1	2,100	740	4
	3	4,500	1.52	71	5.5	8.1	165	2	2,400	726	5
	24.0" (0.61 m)	9,000	1.47	83	5.3	10.3	124	3	2,300	656	5
		18,000	1.46	87	5.2	10.1	128	5	2,500	561	5
		1,125	1.65	52	4.2	6.7	429	1	-	742	5
	6	4,500	1.50	78	5.0	9.4	204	2	2,600	728	5
	42.5" (1.1 m)	9,000	1.46	88	4.7	10.3	161	6	3,100	659	4
		18,000	1.41	91	4.3	10.9	125	36	2,500	429	5
		1,125	1.71	44	2.5	6.3	497	1	1,900	742	4
	9	4,500	1.58	66	4.1	8.2	222	2	2,400	735	4
	125.5" (3.18 m)	9,000	1.47	87	4.2	10.3	150	4	4,200	674	4
		18,000	1.42	84	4.2	10.6	121	93	2,100	346	5
Plantation-grown trees		1,125	1.53	71	4.8	7.8	183	6	-	694	4
	Representative	4,500	1.43	86	4.4	9.6	124	5	-	684	4
	sample	9,000	1.38	90	4.1	10.6	112	9	-	622	4
		18,000	1.36	87	4.2	10.5	112	23	-	494	5
		1,125	1.55	72	4.5	8.6	213	6	-	702	4
	Composite	4,500	1.46	86	4.0	10.6	144	7	-	690	4
	sample	9,000	1.41	95	4.0	11.3	127	8	-	640	4
		18,000	1.37	108	3.8	12.9	101	47	-	450	5

x/ = Massachusetts Institute of Technology

+/ = Canadian standard of freeness

Source: Koeppen and Sitzman 1954

6.731 Morphological studies of butt samples from plantation-grown specimens of A.hunsteinii and A.cunninghamii (Koeppen and Sitzman, 1954)

Tree No.	Species	Tracheid length mm		Ratio length to diameter		Average tracheid diam. mm	Average lumen diam. mm	$\frac{2w}{l}$ 1/	Density lb/cu.ft.	Minute compression failures
		Pith	Near bark	Pith	Near bark					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	A.hunsteinii	2.53	3.72	84	93	0.040	0.030	0.33	24.8	Absent
2		2.04	4.18	58	83	0.037	0.027	0.37	24.7	"
3		1.74	4.60	58	92	0.037	0.027	0.37	23.1	"
4		1.90	5.16	63	103	0.040	0.030	0.33	22.7	"
5		1.93	4.81	64	96	0.041	0.031	0.32	23.0	"
6		1.71	4.84	57	96	0.043	0.032	0.34	23.4	"
7		1.81	4.24	60	94	0.044	0.035	0.31	20.9	"
8		1.57	4.05	39	81	0.044	0.034	0.29	21.2	Some
1	A.cunninghamii	1.71	4.25	57	99	0.034	0.027	0.26	26.2	Absent
2		2.04	4.36	60	95	0.034	0.027	0.26	25.2	"
3		1.65	4.80	59	111	0.035	0.028	0.25	27.0	"
4		1.63	4.00	42	70	0.036	0.030	0.20	24.7	"
5		1.63	4.30	50	78	0.034	0.026	0.30	24.3	"
6		1.95	3.40	54	75	0.035	0.028	0.25	23.7	"
7		1.47	4.20	42	84	0.038	0.029	0.31	24.0	"
8		2.02	3.70	50	66	0.036	0.030	0.20	24.9	"

1/ Where w is the wall thickness and l is the lumen diameter

6.731 * **Morphological studies of butt samples from virgin growth specimens of A.hunsteinii and A.cunninghamii**

Tree No.	Species	Tracheid length mm		Ratio length to diameter		Average tracheid diam. mm	Average lumen diam. mm	$\frac{2w}{l}$ 1/	Density lb/cu.ft.	Minute compression failures
		Pith	Near bark	Pith	Near bark					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	A.hunsteinii	2.16	5.30	54	98	0.046	0.033	0.39	29.6	Present
4		2.25	6.30	56	126	0.047	0.035	0.34	24.9	"
7		1.93	6.71	48	134	0.045	0.035	0.28	28.2	"
8		1.87	7.20	37	120	0.058	0.046	0.26	24.0	Present (numerous)
10		1.75	6.22	-	124	0.047	0.037	0.27	22.6	"
2	A.cunninghamii	2.30	6.09	57	101	0.034	0.026	0.30	25.6	Absent
3		2.85	4.89	71	89	0.037	0.028	0.32	29.0	"
6		2.86	4.03	71	73	0.041	0.031	0.32	28.8	"
9		-	6.46	-	99	0.046	0.029	0.58	28.8	"

1/ Where w is the wall thickness and l is the lumen diameter

* Koeppen and Sitzman, (1954)

Fibres from trees with slow to medium growth rates were found to have a greater average length than those from trees with fast growth rates, an indication that pulps prepared from suppressed trees of plantation-grown species should have a higher average length than the average of the total fibrous material. Further Koeppen and Sitzman found that the fibre lengths of plantation-grown trees reach a maximum at certain heights in the tree. For example, in A. hunsteinii, 48' (14.63m) high, the maximum fibre length was measured at a height of 17' (5.18m) and in A. cunninghamii 78' (23.77m) high, the maximum fibre length was at a height between 11' and 25' (3.35m and 7.62m). Above the 17' (5.18m) level in the 48' (14.63m) high tree and above 25' (7.62m) in the 78' (23.77m) high tree the fibre lengths become progressively shorter. All measurements were from the pith to the bark.

The average fibre length even at the centres of the trees was found to be considerably greater than the average fibre length for other softwoods and the diameter of the fibres was found to increase from 0.03mm to 0.06mm from pith to bark. For other softwoods, such as Spruce and Pine, Mühlsteph (1940)(quoted by Koeppen and Sitzman, 1954) has found that the fibre diameter varies between 0.016 mm and 0.040mm with an average of 0.027mm and that the ratio of length/diameter increased considerably from pith to bark. These variations in fibre length as found by Koeppen and Sitzman are in agreement with Gerry's (1954) observations on the fibre length of A. hunsteinii.

Runkel (1940-42) (quoted by Koeppen and Sitzman, 1954) has found that the ratio 2 W/1 (where W is the cell wall thickness and 1 lumen diameter of a fibre) is important in determining the pulping properties of a given species. Runkel has shown that fibres having values less than unity for 2 W/1 gave good quality paper and for both species of Araucaria, A. hunsteinii and A. cunninghamii the value 2 W/1 was between 0.2 and 0.4 (Koeppen and Sitzman, op. cit).

6.732 Chemical Properties

The following table gives results of chemical analyses of A. hunsteinii and A. cunninghamii:

Analyses of representative samples of A. hunsteinii and A. cunninghamii
Results based on o. d. wood (from Koeppen and Sitzman, 1954)

Analysis for:	A. hunsteinii %	A. cunninghamii %
Moisture content	9.7	8.3
Ethanol-benzene solubles	0.7	0.9
0.1 N NaOH solubles	9.6	8.0
Water solubles	2.7	1.3
Alkali consumption g/100 g of o. d. wood	5.8	3.7
Lignin in wood		
(a) Klason method	31.2	32.4
(b) Halse method	30.9	32.9
Yield of furfural	6.2	5.4
Ash content	0.6	0.5
Qualitative test for tannins	trace	trace
Chlorite holocellulose (on ethanol-benzene extracted wood)	76.1	73.2
Lignin in holocellulose (Halse)	4.2	3.2
Ash in holocellulose	1.7	1.4
Holocellulose, lign- and ash- free (carbohydrate fraction)	70.2	68.6
Mannan in 'crude' cellulose	3.2	3.4
'Pure' cellulose	41.0	39.6

Koeppen and Sitzman found that these results were similar to those obtained from other softwoods, namely, lignin 27% to 33%, yield of furfural 4% to 8%, 'pure' cellulose 40% to 41%, ethanol-benzene solubles 0.4% to 2.5%. Plantation grown A. cunninghamii had higher lignin contents and lower yields of furfural than the corresponding A. hunsteinii trees. But the slower grown trees from the virgin forests contained more pentosan and ethanol-benzene solubles than faster grown plantation species and in general they were found to be similar to the older trees in their chemical composition.

6.733 <u>Sulphate Pulping of A. hunsteinii</u>

Preliminary pulping studies of *A. hunsteinii* have been made by Koeppen and Sitzman (op. cit). Results and conclusions are set out in the table on page 110.

From the figures quoted in this table it was concluded that *A. hunsteinii* pulps prepared by cooking at 160°C (320°F) to 165°C (329°F) had good strength properties and that fibres from this species were more sensitive to high pulping temperatures than those from other softwoods. With raw pulp the decrease in tear factor on beating was found to be less than the medium and well cooked pulps, therefore the raw pulp could be used with advantage in the preparation of high strength papers. It was further concluded that the properties of sulphate pulps prepared from *A. hunsteinii* were comparable with those from Swedish Ljusnan (Pine) sulphate, except that *A. hunsteinii* pulps had a much greater tearing strength (371 to 403 at 1125 rev.) and that as far as it was known, this value for tearing strength of lightly beaten pulps has never been obtained for any other wood species (Koeppen and Sitzman).

6.734 <u>Comparison of Sulphate Pulps from Plantation-grown and Virgin Growth Trees of A. hunsteinii</u>

Pulps from (a) 13 butt samples (plantation-grown and virgin growth), and (b) a representative sample from plantation grown trees and (c) a composite sample from plantation grown trees, of *A. hunsteinii* prepared under the following conditions: total alkali as Na_2, 20% sulphidity, 33%; liquor ratio 5:1; time, 4 hours at 165°C (329°F), gave the results tabulated on page 111

From these values Koeppen and Sitzman found that pulps from trees with very different growth conditions were similar in lignin and furfural yield and permanganate number.

They also compared pulps from plantation grown and virgin growth samples of *A. hunsteinii* selected for evaluation by beating for 1125, 4500, 9000 and 18,000 revolutions. The table of results is not quoted here. Their comments on the values are that the strength properties (especially the tearing factor) of plantation grown *A. hunsteinii* were lower than those from the virgin forests because of the comparatively short fibres, 2mm to 5mm (the plantation grown trees were only 11 years old). Again pulps prepared from the representative and composite samples had similar strength properties. However, it was found that the yields of pulps prepared from the plantation grown trees were 2 to 3 percent less than those from virgin forests.

* Evaluation of sulphate pulps from A.hunsteinii cooked at different temperatures

Cook	Temp. °C (°F)	Beating rev.	Bulk	Burst factor	Stretch %	Breaking length km.	Tear factor	Air resistance sec.	Drainage time sec.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
5A-1	160 (320)	1,125	1.83	55	(not a	6.5	371	1	4
		4,500	1.65	72	clean	8.5	205	3	-
		9,000	1.47	91	break)	10.6	115	12	4
		18,000	1.43	93	3.6	12.0	98	129	5
5A-II	165 (329)	1,125	1.67	56	3.2	6.5	403	1	-
		4,500	1.49	88	4.0	9.8	138	4	-
		9,000	1.41	99	4.2	10.4	114	262	-
		18,000	1.31	97	4.3	11.1	92	-	-
5A-III	170 (338)	1,125	1.63	54	3.2	7.3	204	3	5
		4,500	1.52	64	3.2	9.1	122	6	5
		9,000	1.43	69	2.9	7.9	107	13	-
		18,000	1.35	74	3.6	9.6	94	1,164	-

Chemical data

(The yields and chemical analyses are based on the o.d. wood and o.d. pulp)

Cook	Yield %	Lignin %	Yield of furfural %	Permanganate No.
5A-I	52.0	6.0	3.7	36
5A-II	50.4	5.3	3.8	23
5A-III	46.6	2.0	3.9	12

*(Koeppen and Sitzman,1954)

* Sulphate pulping of A.hunsteinii

(All results are based on oven-dry wood and oven-dry pulp)

Trees	Tree No.	Yield %	Lignin %	Yield of furfural %	Permanganate No.	Fibre length: Average length of whole fibres mm	Fibre length: Average length of total fibrous material, mm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Plantation-grown trees	Butt samples 1	44.3	5.4	6.8	25		
	2	44.9	5.4	6.7	26		
	3	44.8	5.5	6.7	25		
	4	44.6	5.0	6.3	27		
	5	44.3	5.5	6.4	26		
	6	45.6	5.0	6.2	24		
	7	44.9	5.5	6.1	24		
	8	46.0	5.4	6.6	23		
	Repr. sample	46.0	5.1	6.4	25		
	Composite sample	46.8	4.8	6.8	24		
Virgin growth trees	Butt samples 1	49.2	4.1	5.4	27	4.9	3.3
	4	48.0	4.9	4.8	27	5.6	4.0
	7	49.2	3.6	4.4	25	6.1	4.1
	8	47.8	4.0	3.2	24	6.4	4.6
	10	48.6	4.5	5.3	26	5.2	4.6
Average values for fibre length						5.6	4.1

* Koeppen and Sitzman,1954

6.735 Sulphite Pulping of A. hunsteinii

A comparison of the strength properties of pulps of A. hunsteinii prepared by the sulphite process showed some difference. The sulphate process requires economies of scale (that is large scale production in order to be economic). But the sulphite process, using lime and sulphur dioxide as the basic cooking chemicals, can be operated successfully on a much smaller scale because it does not require expensive recovery plant, an essential item in the sulphate process. By evaluating pulps from both the sulphite and sulphate processes Koeppen and Sitzman have shown that the strength properties of lightly beaten pulps were similar to those of conifer pulps prepared by the sulphite process; but the tearing strengths were lower than those of other conifer pulps and 5.8 times lower (at 1125 rev.) than those of the sulphate pulps obtained from the same wood samples. This difference was attributed to the varying chemical composition of the pulps and to different distribution and location of components within the various cell walls.

6.736 Pulps Made From Machine-made and Hand-made Chips

Strength properties of pulps depend on the method of chip preparation. Data obtained from pulps prepared mechanically and hand-chipped samples showed that mechanical chipping caused a marked decrease in tearing strength, although there was no significant decrease in tensile strength (Koeppen and Sitzman, op. cit).

6.737 Blending of A. hunsteinii Pulps with other Pulps

With its very high tearing strength A. hunsteinii (in the unbeaten state) has been found to be very well suited for blending with hardwood pulps to improve tearing resistance. This, for example, has been achieved by blending sulphate pulps from A. hunsteinii with Eucalypt sulphate pulp; comparison of test sheets made from beaten Eucalypt sulphate pulp and from blends with A. hunsteinii pulp showed a gradual increase of the overall strength of the latter. For example, it was found that a blend containing 30 percent A. hunsteinii pulp increased the folding endurance, tear, burst and breaking length by 690, 37, 23 and 9 percent respectively (Koeppen and Sitzman, op. cit). See table on page 113.

Strength Properties of A. hunsteinii and Eucalyptus Sulphate Blend

A. hunsteinii pulp % 1	Eucalyptus pulp (beaten) (%) 2	Additions to A. hunsteinii pulp (unbeaten)			
		Burst factor 3	Tear factor 4	Breaking length(km) 5	Folding endurance 6
0	100	60	106	7.9	170
10	90	69	118	8.0	660
20	80	70	133	8.8	780
30	70	73	147	8.7	1200
50	50	77	156	9.3	1900
60	40	70	199	8.6	2200
75	25	73	299	8.4	2900

6.738 Comparison of Strength Properties of Araucaria Pulp with those of other pulp, e.g. Swedish pulp

Koeppen and Sitzman (op. cit) have compared the strength properties of Araucaria pulps with those of Swedish sulphate pulps. They found that the 'strength numbers' * of sulphate pulps prepared from hand-made chips of the virgin growth trees of A. hunsteinii and A. cunninghamii were higher (12 percent higher) than Swedish Ljusnan sulphate pulp. The pulps from mechanically chipped A. hunsteinii gave practically the same strength number as the Ljusnan sulphate pulp. Sulphite pulps gave a strength number 24 percent lower than the sulphate pulp prepared from the same sample.

6.739 Conclusions on Pulping Tests

Koeppen and Sitzman have summarised their pulping studies in the two Araucaria species as follows:

1. Plantation grown trees differed slightly in yields of furfural and ethanol-benzene extractives from virgin growth trees, but in

* 'Strength number' is a composite value in which the tear, burst and folding endurance results for three different beating points are incorporated. This enables evaluations to be compared in a very simple manner. However, its method of derivation or determination is not considered necessary here.

general all the trees were found to be similar in their main chemical components.

2. The average tracheid length for unbeaten kraft pulp prepared from virgin growth trees was 5.6mm. The cell-wall thickness and the ratio of wall thickness to diameter of lumen indicated that both species A. hunsteinii and A. cunninghamii would produce pulps with good strength properties.

3. The sulphate and sulphite processes gave good yields of pulps, 44 to 46 percent for plantation-grown trees and 48 to 59 percent for virgin growth trees, according to the cooking conditions. Pulps from the sulphate process were much superior in their strength properties to those from the sulphite process.

4. In general, strength properties of the pulps compared favourably with those of good quality commercial sulphate pulps, but very high tearing strengths were a feature of the Araucaria sulphate pulps. Fibres from these woods were more rapidly damaged by high pulping temperatures and by beating, than fibres from other softwoods. Even the most gentle beating considerably reduced the tearing strength.

5. Sulphate pulps of A. hunsteinii from hand-made chips gave higher tearing strength, folding endurance and bursting strength than pulps from machine-made chips. The lightly beaten sulphate chips of A. hunsteinii had a much higher tear factor, with burst factor, folding endurance and tensile strength comparable with good quality commercial sulphate pulps.

6. Koeppen and Sitzman concluded that the result of their investigations indicate that it would be possible to obtain (or grow) in the tropical region a raw material for pulping which would be comparable with the best European softwoods.

7.0 PRINCIPAL USES

Parana Pine, Hoop Pine, Klinki Pine, Bunya Pine and, to some extent, Norfolk Island Pine are used principally in the manufacture of sawnwood (lumber), veneer, plywood and for pulp and paper.

7.1 Sawnwood

The sawnwood is employed chiefly for building construction and is well adapted for the inside finish of houses, stores and public buildings. The wood is used as mouldings, casing, flooring, lining, ceilings, walls, partitions, rafters, studs, stair work, joists, joinery and scantlings. It is suitable for sheathing, siding, sash, blinds and window frames and outside doors and frames. But as the wood lacks durability it is necessary to apply appropriate preservative treatments when used out of doors and in situations favouring decay. Both Hoop and Klinki Pines can be used as substitutes for Spruce in the aircraft construction industry.

Large quantities of sawnwood go into the furniture and cabinet making industry and it is used for cheaper classes of furniture such as kitchen tables, handles for household tools, inner and hidden parts of furniture including case goods and fixtures, broom and brush handles, agricultural tools, cask heads, printers' blocks and bee keepers' requirements In Queensland, Australia, Hoop Pine thinnings are being sold to sawmills which cut out the knotty nodes and fingerjoint the internodes thus producing large clean timber surfaces, free of knots, which have many uses.

The wood is suitable as shipping containers, including boxes, cases, crates for packing house products, nails, rubber, mineral water, wine, beer and other liquors and also for vegetables, fruits and butter, provided that an anti-taint spray (casein and formalin mixture) is applied.

Other uses include fence posts or fence pickets, battery separators, as sticks and boxes in the match industry and as slack barrel staves in cooperage. The wood is adapted to these uses because it has uniform texture, freedom from resins and lacks odour.

7.2 Veneer and Plywood

All make excellent material for the manufacture of veneer and plywood. Veneers are normally produced by the rotary cut process. The wood is readily glued with various types of glue. The heartwood is valued as veneers for panelling because of the attractive colour and both the sapwood and the heartwood can be used for such purposes as plywood core stock, cross banding and outer plies.

7.3 Pulp and Paper

Because of their long fibres wood residues and materials from thinnings can be used for pulp and paper.

7.4 Other Uses

Residues from Parana Pine can be utilized in the production of calcium-acetate, methyl-acetone, charcoal and crude tar by a relatively cheap method of carbonization (Spitzner and Chicarello, 1954). By this process it has been possible to obtain from one cu. ft. (0.028 cu. m) of

Parana Pine branches: 120 kilos of calcium-acetate, corresponding to 10 kilos of acetic acid at 80%, 20 kilos of crude tar and 35 kilos of crude methylene.

A. excelsa has been used mainly as an ornamental tree in parks, avenues and in residential areas, and as a Christmas tree because of its beautiful appearance.

7.5 Favourable and Unfavourable Characteristics of the Wood

Gerry (1954) has summarised the chief characteristics of Klinki Pine and listed the following points for and against the wood. Parana Pine and Hoop Pine share some of these characteristics with Klinki Pine.

Favourable characteristics

(i) attractive colour
(ii) straight grain
(iii) light weight
(iv) low shrinkage, giving rise to dimensional stability
(v) medium density, hardness and strength
(vi) uniform texture
(vii) no matching problems
(viii) no filler for finishing
(ix) high percentage defect free
(x) easily seasoned and glued
(xi) easily treated with preservatives and finishes
(xii) holds fasteners well
(xiii) long fibred

Unfavourable characteristics

(i) soft and hence marks easily
(ii) not termite or decay resistant
(iii) may contain compression wood, giving rise to compression failures
(iv) sapwood may contain torn fibres ('fuzzy')
(v) susceptible to blue stains and moulds

8.0 TREE BREEDING AND TREE IMPROVEMENT PROGRAMMES

8.1 Araucaria angustifolia

Not much has been done on the tree breeding or tree improvement programme for Parana Pine. However, the little that has been done appears to be in the experimental stages and there are indications of great potentialities in this direction. Pahlen (1960) has shown that A. angustifolia has the same chromosome number (2N = 26) as A. araucana, A. bidwilli and A. cunninghamii.

8.11 Hybridisation

Tesdorff (1956) has reported the results of crosses made between A. araucana and A. angustifolia. Crosses in both directions were carried out between the above two species with a view to combining the rapid growth of A. angustifolia, a species found at a latitude of 26° in the subtropical Misiones territory, Argentina, with the timber qualities of A. araucana, which grows in the colder Neuquery territory at a latitude of 39°. The seedlings from the crosses inherited the morphological characteristics of the maternal parent, irrespective of the directions in which the cross was made. It was found that the progeny of the cross A. angustifolia x A. araucana were the more vigorous and grew more rapidly than the progeny of the reciprocal. It was hoped to obtain from these crosses trees suitable for large-scale cultivation in Central Argentina at a latitude of approximately 32°.

A number of other hybrids have been attempted in the Araucarias. For example, in Queensland, Australia, among the crosses that have been attempted is that between A. cunninghamii and A. angustifolia (Nikles, 1962). The result of such crosses have not been evaluated or reported.

8.12 Vegetative Reproduction

Like several other Araucaria species, Parana Pine has the ability to produce coppice shoots. It can be raised vegetatively from cuttings (Wormald, op. cit). Wormald has expressed the view that 'if it is necessary to increase the area under plantations (in Kenya) rapidly it should be quite feasible to sacrifice a plantation by using the leading shoots as cuttings and each tree will then produce a cluster of new leaders which can in turn be used to produce cuttings'.

It has yet to be shown by experiment that trees produced from such stem cuttings are as good (or even better) in all respects as trees raised from the seed. Otherwise it would be unwise to 'sacrifice' a flourishing plantation only to produce stem cuttings. One has also to consider the expenditure of money involved in raising Parana Pine in the nursery, planting it out in the field and the additional expenses involved in producing stem cuttings.

8.2 A. hunsteinii

There is at present no tree breeding or tree improvement programme for Klinki Pine, although crosses between it and Hoop Pine have been attempted (without success) in Queensland. Its excellent form makes the selection of plus trees less urgent in this species than in most other tropical timber trees. However, Suttie (1968) has stated that consideration is now being given to the selection of parents of Klinki and Hoop Pines and that pioneer testing of wood properties is under way; grafting techniques for these species are also under investigation in New Guinea.

8.3 Hoop Pine

Of all the Araucaria species, Hoop Pine is the only one which has received much attention in tree improvement programmes in the broadest sense. Up to the present work is still in progress to find out the best way of improving or inducing the desired qualities in Hoop Pine. In Queensland Hoop Pine is being selected on the basis of straightness and vigour.

The tree improvement programme for Hoop Pine has been developed along five main lines, namely (1) provenance trials, (2) vegetation propagation, (3) seed orchards, (4) progeny trials and (5) hybridisation. These lines of research will be examined one by one to determine what progress has been made and to indicate any outstanding problems.

8.31 Provenance Trials

Hoop Pine has an extensive geographic distribution and considerable provenance variations within the species exist. This has been recognised although the pattern has not been fully investigated (Nikles, 1962). The aim of a provenance trial is to establish plots using seed from a number of sources covering the climatic range of the species in its native habitat. Later these plots will permit sound comparisons to be made between sources (Haley, 1960). This has been done for Hoop Pine in Queensland during the past 38 years and Slee and Reilly (1966) have shown that differences in growth rate exist between seed sources as shown in the following table:

8.311 Comparison of eight Queensland Provenances of _Araucaria cunninghamii_ at 25 years old at two test centres in Southeast Queensland

Provenance	Total merchantable volume per acre (per ha), including thinnings, expressed as percentage of Gympie provenance		
	Yarraman *	Imbil **	Average
Jimna	128.0%	133.7%	131.4%
Kalpowar	128.7%	124.2%	126.0%
Gallangowan	121.1%	124.8%	123.2%
Benarkin	120.5%	121.6%	121.1%
Yarraman	122.8%	119.6%	120.9%
Warwick	126.4%	113.4%	118.7%
Kilkivan	116.7%	101.2%	110.7%
Gympie	3442 cu. ft. (240.85 m^3/ha)	4922 cu. ft. (344.41 m^3/ha)	4182 cu. ft. (291.63 m^3/ha)

* Randomised block layout of 2 replications. Unit plot 96 trees.

** Simple adjacent block layout. Unit plot 3 rows of 66 trees.

The investigators found to their surprise that the local provenance was not always the best volume producer and the most vigorous provenance to date were Jimna and Kalpowar, whilst the Kilkivan and Gympie seed sources appeared poorest. The straightness and height growth of the New Guinea provenance was found to be inferior to the Queensland provenances and the New Guinea provenances exhibit different bark, needle and crown characteristics from the Southern Queensland sources.

Variations of Hoop Pine provenances, one from Kalpowar (Queensland) and the other from Bulolo (New Guinea) have been observed in Sabah by Nicholson (1964). For details see para 3.22.

8.32 Vegetative Propagation

8.321 Cuttings

The possibilities of propagating Hoop Pine vegetatively have been outlined by various workers. Haley (1957) found it extremely difficult to strike "cuttings from branches old enough to give any indication of their genetical make-up," and the few successful cuttings which were obtained retained the sprawling habit of side branches. But successful strikes of from 68-92% were obtained with cuttings from leading shoots of nursery stock two to three years old and the cuttings developed normally in the field. This is similar to the results which Wormald (op. cit) obtained with Araucaria angustifolia in Kenya (para 8.12 above). Slee and Reilly (op. cit) have reported 67% success, achieved in one small test on cuttings from 6 year old orthotropic shoots, (i.e. shoots which grow vertically upwards as distinguished from those which grow obliquely or horizontally, plagiotropic). The cuttings were soaked for 24 hours in a hormone solution similar to that used in Southern Pine as reported by Mergen (1956) (quoted by Slee and Reilly, 1966). The present approach in Queensland is to attempt to strike cuttings taken from orthotropic shoots growing from bud patch grafts of old trees.

8.322 Grafting

A successful 'bark patch' grafting technique has been developed for Hoop Pine by Nikles (1961) and takes of 90% or higher can be achieved with the use of suitable scion material. The technique was based on the observation that in Hoop Pine and with several other members of the Araucariaceae:

(a) the terminal bud of the stem and the dormant buds in the bark of the trunk are the only meristems normally capable of producing shoots which develop orthotropically;

(b) the terminal bud (which gives rise to the leading shoot) may have less powerful apical dominance than the dormant buds in the bark (which give rise to the branch shoots) so that a branch may replace the leader;

(c) secondary leading shoots can be produced from the main stem following the loss or removal of the original leader and grafts or cuttings employing such secondary leading shoots develop the normal stem habit.

The actual 'bark patch' graft consists of the use of patches of bark taken from near the tip of the main stem and side grafted onto well established seedlings in the field. The procedure as described by Nikles is as follows:

Vigorous plants 5' - 7' (1.52m to 2.13m) high are chosen (in Queensland this size is reached in the second year after planting in the field). Scions are obtained by decapitation of old trees and from coppice produced at the base of the stumps. For each graft, a piece of bark 2" (5cm) long, together with a thin sliver of wood, is cut from the severed top. The scion should contain ten or more leaves. A flat cut is made on the main stem of the seedling stock at a height of about 5' (1.52m) and of such depth that the face of the cut is approximately the same size as the scion. The scion is held firmly against the stock and bound with plastic tape. The top is cut off the stock plant just above the graft. Within a few weeks the union should be formed and by six weeks dormant buds should begin to elongate, usually only one per scion. Earlier observations in Queensland showed that in almost all cases where good union was formed, elongation of the secondary shoots followed, usually within three months.

But unfortunately this very promising 'bark patch' grafting technique is now beset by the incidence of incompatability. This usually occurs about 3-4 years after grafting. The symptoms are pronounced swelling above the union, followed by chlorosis and death of the scion. Retarded growth is also another feature of some healthy grafts, and pruning of the stock produced a more rapid decline in health (Slee and Reilly, op. cit). However, in Queensland several other grafting trials have been established to investigate the effect on incompatability of:

(1) scions of different physiological ages

(2) the(patch) grafting technique

(3) other grafting methods

Also Lamb (1966) has reported that in Queensland attention is now being given to the parents, the age of the stock, the age of the graft, the height above ground of the point of budding, the vigour of the stock and above all the possibility of rooting cuttings and so bypassing graft incompatability.

8.33 Seed Orchards

*Clonal seed orchards have been established in Queensland. Clonal rather than seedling orchards were thought to be essential because of the long delay before enough pollen is produced by Hoop Pine.

* A clone is a collection of individuals derived from the same parent by vegetative reproduction.

Pollen production by Hoop Pine does not reach an optimum level until the trees are at least 30 years of age. It is expected that in clonal seed orchards the delay will be halved.

In Queensland the oldest orthotropic patch grafts are now nearly eight years old but so far the production of male amenta has not been reported and at present the development of a suitable technique of grafting pollinator branches on to orthotropic leader grafts is being investigated. If it is successful it would substanially reduce the delay before pollen production.

Plantations are therefore being searched for superior adult Hoop Pine phenotypes and some trees have been selected as seed orchard parents. The flowering habit of Hoop Pine has been mentioned in para 3.41. It was pointed out that flowering normally occurs in December to January, although several trees have been found to flower as late as April and May. The suggestion is that this peculiar flowering habit does appear to be under strong genetical control. To overcome this, ten early and ten late flowering trees have been selected as plus tree parents for the seed orchard. Each tree has been selected for its superior straightness and vigour.

8.34 Progeny Trial

It is not possible to assess from the external appearance of a tree whether or not it can transmit its desirable characteristics to its progeny. The aim of a progeny trial is, therefore, to determine whether the offspring of a given tree selected for particular desired qualities have inherited those qualities from the parent. In Queensland Hoop Pine orchards of parent trees are tested by what is called 'a two-way di-allele system' using randomised blocks of 49 - tree square plots, 9 - tree square plots and 10 - tree line plots (Slee and Reilly, op. cit). Trees possessing specific outstanding traits are crossed in order to test specific combining ability. But since the pollination season of Hoop Pine is extremely long (extending from December to May in Queensland) suitable methods of pollen storage have been developed and it has been shown that pollen can be stored successfully for two years at $5^{o}C$ ($41^{o}F$) and 30% relative humidity.

8.341 Controlled Pollination

Stages of receptivity of Hoop Pine strobili (cones) have been investigated by Nikles (1965). In an investigation to determine the limiting stages of the developing cone of Hoop Pine during which pollen may be received and also the optimum stages and period of receptivity, Nikles found that the maximum receptivity for all trees investigated was in the length range of approximately 0.3" to 1.1" (0.76cm to 2.79cm).

Cones within this range of size are at the optimum stage for pollination. For complete safety from contamination, strobili must be isolated before bud opening (or before any pollen is shed) and bags* used in controlling pollination should be left in position until conelets are at least 1.5" (3.81cm) long or well after the pollen has been shed.

A preliminary assessment of open pollinated and control-pollinated progenies indicates that:

(i) straightness, branch angle, interwhorl length are strongly heritable;

(ii) cross-pollinated progenies were more vigorous than open and self-pollinated progenies of the same cone parent. Selfing was found to depress growth rate. This is illustrated in the following table:

Comparison of average G.B.H. and height of self, open and cross pollinated progenies of three cone parents of Hoop Pine at 8 years old

Progeny Type	Average G.B.H.	Average Height
Self	9.3" (23.62cm)	16.6' (5.06m)
Open Pollination	12.9" (32.77cm)	24.4' (7.44m)
Cross Pollination	14.9" (37.85cm)	29.7' (9.05m)

It was found that self-pollination of ten trees revealed frequent depression of seed viability and seedling growth rate but no reduction of cone and seed set.

8.35 Hybridisation

8.351 Interspecific

The following crosses have been attempted with Hoop Pine (Nikles, 1962; Slee and Reilly, 1966):

Araucaria cunninghamii

x Araucaria excelsa R. Br.
x A. columnaris (Foster) Hook
x A. araucana
x A. angustifolia (Bert.) O Kuntze
x A. bidwillii Hook
x A. hunsteinii (syn. A. klinkii)

* Of all types of bags tried in controlling pollination, Nikles found the duck bags with mellinex window flap and measuring 22" x 14" (55.88cm x 35.56cm) to be the most promising.

These crosses have been unsuccessful and Slee and Reilly have concluded that inter-specific hybridisation as a means of genetic improvement is not promising. On the other hand Tesdorff (op. cit) has reported of the excellent progress made by the cross between A. angustifolia and A. araucana (see para 8. 11).

8.352 Intraspecific or Inter-racial

Inter-racial. Attempts have been made to cross superior phenotypes of different provenances of Hoop Pine. Significant gains in growth rate are expected from such crosses. For example, one such cross, New Guinea x Southeast Queensland provenance, has shown outstanding seedling vigour.

8.36 Present Programme of Tree Breeding in Queensland

Nikles (personal communication with Lamb) is proposing to start the nursery stage in August 1968 of a comprehensive provenance trial of Hoop Pine resulting from seed collections at some 45 localities throughout the entire range of the species in New Guinea and Eastern Australia. Seed collections from some 500 individual trees have been made and progeny from such trees will be kept separate in the nursery and in the field. Outplantings will be made in at least two years at each of six or more locations. Already a strong geographic trend in Hoop Pine seed size has been discovered.

Other lines of research in Queensland include an assessment of the variability of frost hardiness in Hoop Pine with a view to selective breeding for increased hardiness. This will be done in the first instance under artificially controlled conditions and later the survivors will be tested in the field. A study of the occurrence and delineation of frost sites in Hoop Pine areas has been completed and it is hoped to publish the results soon. It is also hoped to bring up-to-date the results of work on the propagation of Hoop Pine subsequent to earlier work on grafting (1961-62) and to detail the progress of the grafted orchard. In the Imbil orchard there is already encouraging flowering just two years after grafting. Nikles also hopes to publish the work already done on the flowering characteristics of Hoop Pine, the development of methods to control pollination and on the morphology and embryology of the species.

The foregoing are the main lines of research on which attempts to improve certain desired qualities in Hoop Pine have been directed. But a Hoop Pine tree breeder is faced with a number of problems. These are (i) the peculiar flowering habit of Hoop Pine; Hoop Pine trees produce flowers and seeds at irregular intervals with about 4 years between general crops, (ii) it does not produce pollen in large and sufficient quantities until it is about 20 years of age and the optimum age of heavy pollen production is at least 30 years, (iii) by the time the male amenta are produced the trees have attained a height of about 80' (24.38m) and this makes the work of controlled pollination difficult and dangerous and (iv) there is the problem of incompatability which has reduced the number of successful clones produced by means of the bark patch technique.

8.37 Conclusions on Tree Improvement

In spite of these problems, however, the tree breeding programme with Hoop Pine has shown some promise. For example, through progeny tests important characters have been shown to be strongly heritable and progress has been made in the establishment of cuttings. Provenance trials, also, have shown considerable difference in growth rates between geographic sources and inter-racial hybridisation hold some promise.

9.0 CONCLUSIONS

The genus *Araucaria* contains species capable of growing successfully on fertile sites from the equatorial humid forest zone to the subtropical climate where frost becomes the limiting factor for all but *A. araucana*.

They can be used to replace mixed tropical hardwoods and produce large concentrated volumes of utility timber for many purposes near manufacturing plants.

Their spread around the tropics from Australasia and Brazil has been frustrated by problems of seed supply which can now be overcome by rapid air transport and the use of low temperature containers.

They are expensive to establish not only because of the cost of seed but also because of high nursery costs and their slow early growth till the 5th year. However their rate of growth accelerates and in Queensland Hoop Pine crops increment was still increasing in the 40 year old plantations.

Their excellent form makes them economical to convert for use. They can produce pulp as suitable for blending with hardwood pulps as temperate species such as Spruce.

The working qualities of the wood and veneer qualities are excellent and thinnings can find a market.

So far no enemies limit their use in suitable sites and climates.

They must be protected from fire but can be the best species to grow where cyclonic storms occur.

More extensive use of the species will follow if seed stands are established in regions suitable for their growth on a sufficient scale to provide local seed supplies. Till this is accomplished Hoop Pine will be the species most widely planted because of its smaller seed and the greater length of time its seed retains viability.

They are nôt suited for afforestation of infertile sites where the tropical pines are superior producers but they will probably maintain the fertility of rainforest sites better than Pines, and suppress regrowth of the hardwoods.

Owing to their isolated dispersal within hardwoods and on islands provenance variation is great and is already being used in Hoop Pine in a tree improvement programme. Seed importers should choose the best provenance for their local conditions.

More extensive use of some of the species as decorative and avenue trees, intelligently placed, could later provide a source of seed for plantations.

It is unlikely that very rapid expansion of Araucaria plantations will occur in the near future but that a gradual increase in interest in these species will follow increased availability of their seeds.

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