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FAST GROWING TIMBER TREES
OF THE LOWLAND TROPICS

No. 4



PINUS MERKUSII

Compiled by E.N.G. COOLING
Senior Research Officer

COMMONWEALTH FORESTRY INSTITUTE
DEPARTMENT OF FORESTRY
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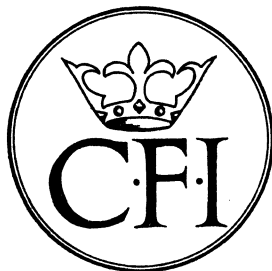
DECEMBER 1968





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Plate 1.

Emergent *P. merkusii* over poor quality dry Dipterocarp forest near Baw Luang, Northwest Thailand.

D. b. h., 65 cms; height, 28m; altitude, 900 m approx.

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1.0

INTRODUCTION

Pinus merkusii is one of the few truly tropical pines in the world and is unique in that its natural distribution just crosses the equator into the southern hemisphere. This pine is extensively distributed in southeast Asia occurring in the Indian Northeast Frontier Agency (and possibly Tibet), Thailand, Laos, Cambodia, Vietnam, Sumatra and the Philippine Islands of Luzon and Mindoro. It has a large altitudinal range from a few feet above sea level to over 1,800 metres, is found on a diversity of soils over many different parent materials, and under climates which vary from markedly seasonal (nearly six months without rain), to constantly humid equatorial conditions with little or no moisture deficit.

Several reports (Anon, 1954; Buys et al, 1928; de Veer et al, 1954; Moon, 1942) indicate that P. merkusii produces a strong timber of good quality, that it can be used as pulpwood and that it provides a good yield of high quality resin.

In view of the quality of the produce and the ability of the species to grow at low altitudes in the tropics, Pinus merkusii deserves increased attention as a potential plantation species in tropical and subtropical countries, including some in which it occurs naturally but in remote areas or places where the forest has been depleted by fire, exploitation or other causes.

Probably as a consequence of its wide geographic range this species differs considerably in growth and other characteristics according to exact origin (provenance) but no really comprehensive study has yet been made of the species throughout its natural habitat.

The object of the tour reported here was to make a preliminary survey of as much of the known range of the species as possible in order to:

- (i) gather information on its botanical and silvicultural characteristics in different localities
- (ii) classify the various provenances with the aid of any differential traits observed and
- (iii) investigate the seed supply position and, if possible, obtain enough seed of the different provenances to permit comparative trials to be made in several regions in the tropics.

In addition to the silvicultural and ecological notes made, botanical specimens, oleoresin samples and some increment cores were collected in most areas visited and brought back to Oxford for comparative studies.

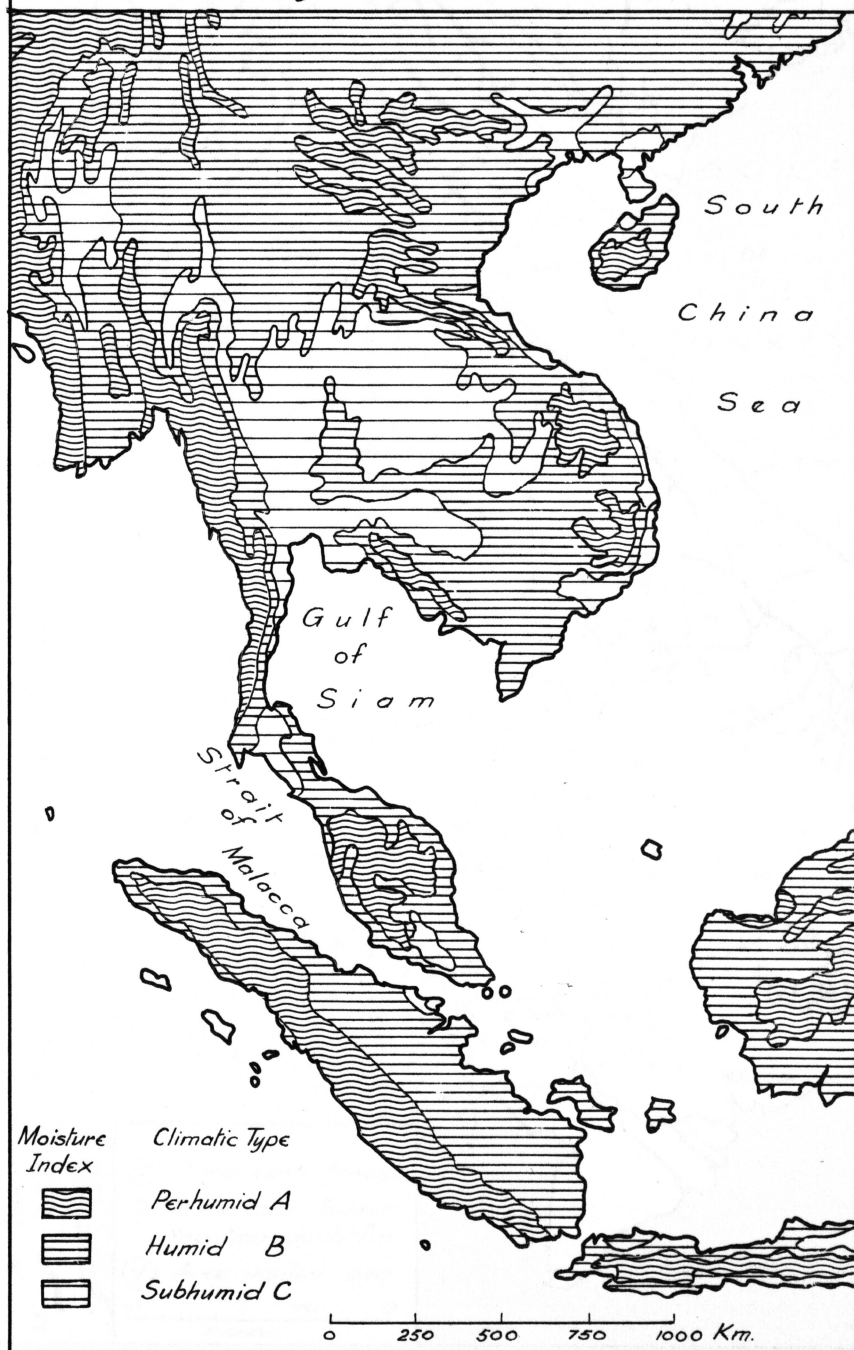
The countries visited were: Thailand, 21 days; Cambodia, 10 days; Vietnam, 10 days; Laos, 6 days; Indonesia (Sumatra and Java), 22 days. Attendance at the Symposium on man-made forests held in Canberra during April 1967 provided an opportunity to see some research plots of Pinus merkusii as an exotic in Queensland and in Territory of Papua and New Guinea. It was unfortunately not possible to arrange a visit to the extensive stands of this species reported to occur in Burma.

The primary purpose of this report is to make the salient observations available to field officers as quickly as possible. General background information and data on the climate, physiography, geology, soils and vegetation of each of the countries visited have also been provided to assist those who may wish to compare conditions in their own countries with the natural habitat of P. merkusii, or to undertake seed collection in the field.

A notable feature of this tour was the excellent co-operation and assistance afforded by all Forest Departments visited and the kindness and great hospitality of the many Forest Officers whom I met in the course of my travels. To all I extend sincere thanks for unfailing efforts to ensure that my mission was both successful and enjoyable.

MAP I. MOISTURE REGIONS, SOUTH-EAST ASIA

(Enlarged from Moisture Regions of Asia
by J. R. Mather)



MAP 2. DISTRIBUTION OF *PINUS MERKUSII* IN THAILAND, LAOS, CAMBODIA & SOUTH VIETNAM

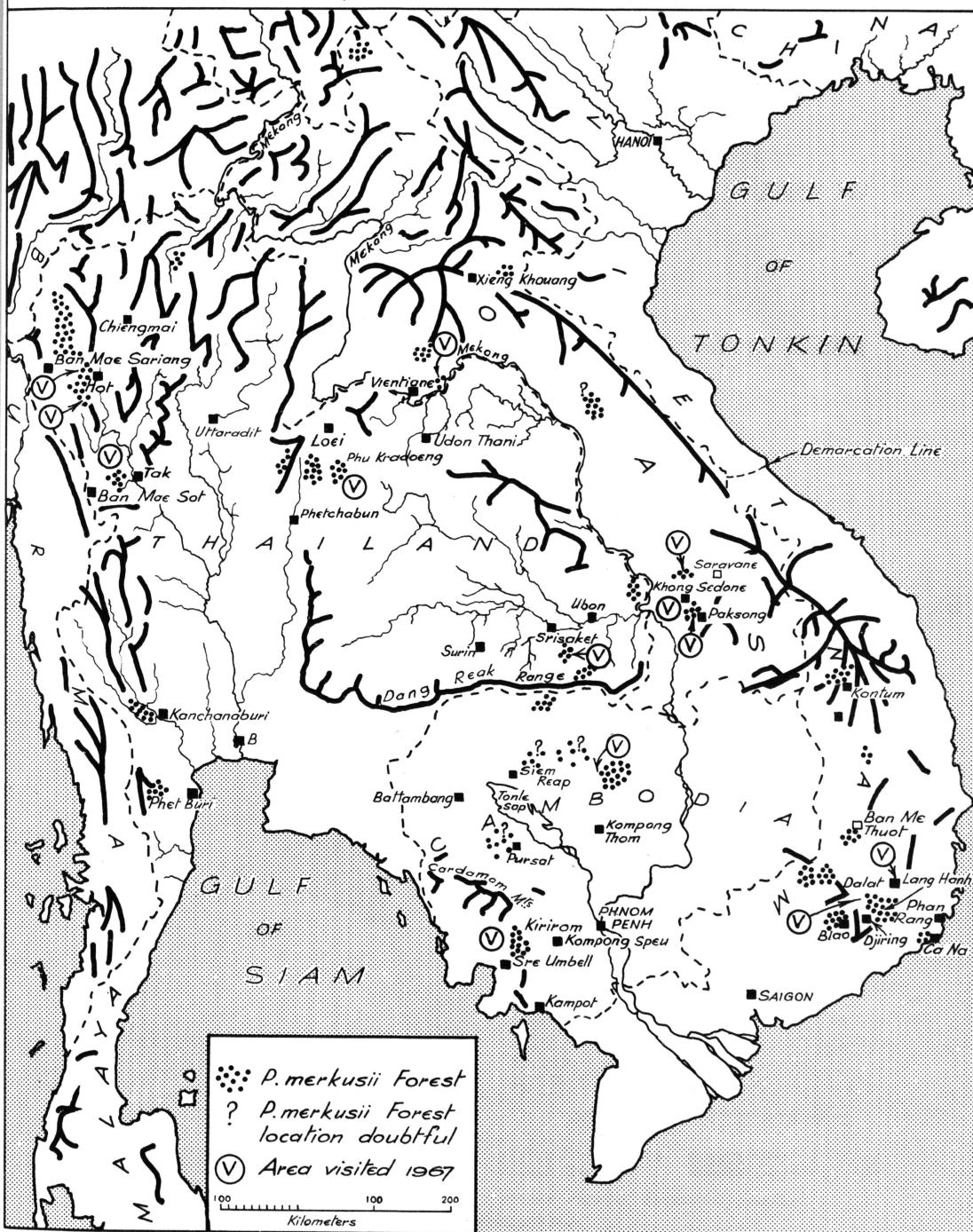
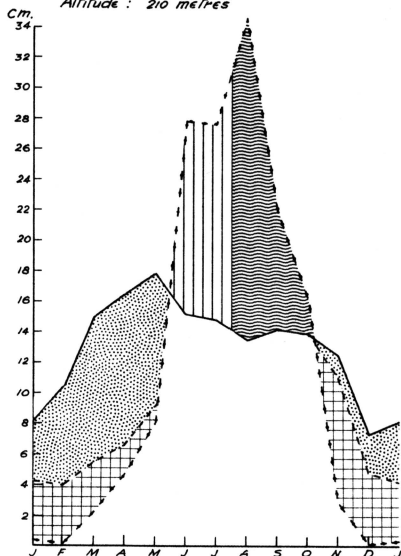


FIG. 1. WATER BALANCE DIAGRAMS: THAILAND

BAN MAE SOT, THAILAND

Location: $16^{\circ}40'N$, $98^{\circ}33'E$

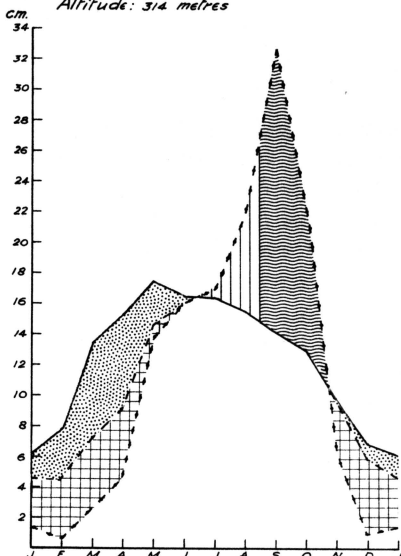
Altitude: 210 metres



CHIENG MAI, THAILAND

Location: $18^{\circ}47'N$, $98^{\circ}59'E$

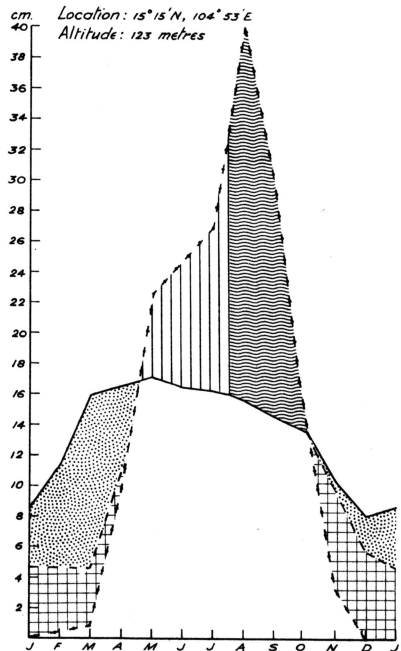
Altitude: 314 metres



MAUNG UBON, THAILAND

Location: $15^{\circ}15'N$, $104^{\circ}53'E$

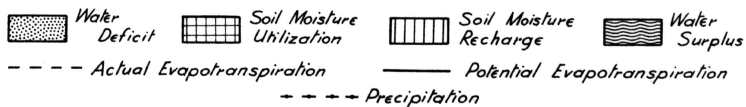
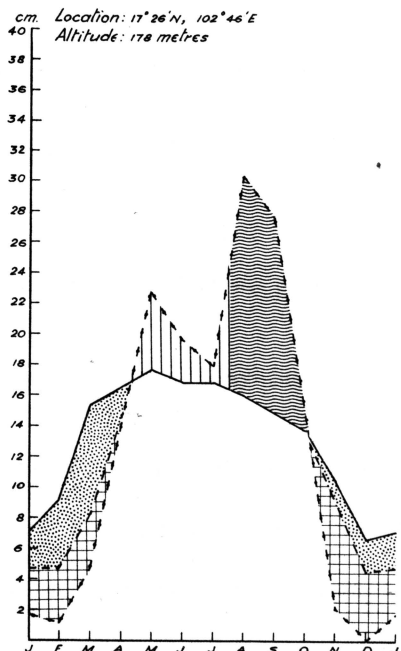
Altitude: 123 metres



UDON THANI, THAILAND

Location: $17^{\circ}26'N$, $102^{\circ}46'E$

Altitude: 178 metres



2.0 THAILAND

2.1 General

The Kingdom of Thailand or Prathet Thai (Land of the Free) is located in the Indo-Chinese peninsula of Southeast Asia, between 5° and 21° N latitude and 97° and 106° E longitude. The total land area is about 513,000 square kilometres. The population totals some 26,000,000, giving an average density of about 50 per square kilometre, which is low for Asia.

Thailand is roughly axe-shaped in outline, with the handle extending southwards down the Malay Peninsula. Bounded on the west and northwest by Burma, on the north and northeast by Laos, to the east and southeast by Cambodia and in the south by Malaysia, the country is about 1600 kilometres from north to south and some 800 kilometres east to west at the widest point. Thailand encircles most of the Gulf of Siam, the coastline being some 2000 kilometres in length.

Rice cultivation, mainly on the central plain watered by the Chao Phraya River, is a highly important agricultural activity. According to figures given by Dobbie (1966) some 13.9 million acres were under rice in 1960. Fishing and freshwater fish culture is of increasing importance. Teak logs and timber are valuable exports. Dobbie reports that, after wartime stagnation, teak extraction has expanded and exports were worth \$21,000,000 in 1963.

2.2 Climate

The tropical climate of Thailand is governed by monsoons. Basically there are four seasons:

1. The southwest monsoon; rainy season, May-September (often with a period of drought in June or July).
2. The retreating southwest monsoon; transition period, October.
3. The northeast monsoon; cool dry season, November-February.
4. The retreating northeast monsoon; hot and relatively dry transition period, March-April.

The narrow Kra Isthmus to the south is an exception to this pattern, having a North Malayan type of climate with rain at all seasons and two distinct maxima. The Cardamom outliers in the southeast of the country near the Gulf of Siam constitute another small area of high rainfall and receive from 1500 mm to over 4000 mm per annum, no month having less than 62 mm of rain.

In general, however, Thailand has a savanna type climate with moderate rainfall and three to five months of fairly cool dry season.

Owing to the north-south mountain chain along the western side of the country and its influence on the southwest monsoon coming in across the Bay of Bengal and the Andaman Sea, elevation and aspect greatly influence the amount of precipitation received in various localities. For example the central depression is distinctly dry, receiving rain only when the air stream comes directly from the south; at other times it lies within the rain-shadow of the mountains to the west. Precipitation on these plains averages 1000 to 1500 mm, except for a belt nearest to the mountains where it is less than 1000 mm. Similarly the Korat Plateau receives less than 1500 mm, and in parts under 1000 mm, but the higher edges of the scarp are much wetter with up to 3000 mm of rainfall. Falls of up to 2400 mm are experienced on the western slopes of the mountains along the Burma border, between about 14° and 17° N latitude, where they are relatively close to the Gulf of Martaban. Further to the north precipitation again decreases to the order of 1000 to 1500 mm, with drier pockets.

The annual rainfall zones have been mapped to a scale of 1 : 2,500,000 on the basis of records covering a thirty year period 1931-1960. This map, produced in 1964, is available from the Royal Thai Survey Department.

From an agricultural standpoint, mainly rice-growing, the climate has the drawback of considerable variability in monthly precipitation which may be as great as 50 to 100 percent above and up to 50 percent below normal (Xujati-Kambhu et al., 1961). This may be of relevance in determining seed years in tree species and the success of natural regeneration and possibly of plantations as well. In areas of low relief the seasonal nature of the rainfall causes flooding which is especially pronounced in the central plains but is

also experienced on the Korat Plateau and results in periodic inundation of the forest land, including some of the pine areas.

Rain often falls as afternoon or evening storms but may be in more or less continuous bursts over several days. Cyclonic storms resulting from pressure areas over the South China Sea cause heavy rains in June but by July a decrease may occur as the storms have in general moved north of Thailand. The return of the storms in a southerly movement in September often causes particularly heavy rainfall on a wide front.

The temperature over most of the country is fairly constant throughout the year. At Bangkok on the coast of Central Thailand the average daily maximum temperature ranged from 25.6°C in December to 35°C in April, while the average daily minimum temperature ranges from 20°C to 25°C in the same months. Comparable figures for Chiang Mai at 396 m altitude in the north are maximum temperature 25.6°C and 32.2°C , minimum temperature 25°C for both December and April. The diurnal range is greater, especially in the dry season in the north when the nights are much cooler than the days.

Relative humidity at 12.30 p.m. ranges at Bangkok from a low 53% in January to a high 70% in September and October. At Chiang Mai a low 40% is reached in March and a high 73% in August.

The direction of the wind is largely determined by the flow of the tropical air masses on the monsoon pattern. Owing to the sheltered position, typhoons from Indo-China and the South China Sea are generally unknown in Thailand and tornadoes are infrequent. Average wind velocity is low throughout the mainland except during occasional cyclonic storms.

Water balance diagrams for four stations in Thailand are presented in Fig. 1. These diagrams are based upon the average climatic water balance data published by the C.W. Thornthwaite Associates Laboratory of Climatology (Mather, editor, 1963). The seasonal course of precipitation and evapotranspiration is shown by the diagrams which include:

- (i) potential evapotranspiration
- (ii) precipitation
- (iii) actual evapotranspiration
- (iv) the storage of moisture in the soil
- (v) water deficit and water surplus

All values are expressed in millimetres and the basic data employed were computed for conditions of soil and plant cover which correspond to soil moisture storage of 300 mm (Mather, editor, 1963).

At Appendix I will be found references to publications dealing with the concept of, and methods of applying, the climatic water balance as developed by Thornthwaite, Mather and associates. A recent publication, *Bioclimats du Sud-est Asiatique* (Gaussen, Legris and Blasco, 1967), not available to me in time, has not been consulted but appears very relevant. It includes a detailed map to a scale of 1 : 2,500,000 showing bioclimates based on precipitation, temperature of the coldest month, and the number of dry months.

The significance of the water balance charts for Thailand in relation to pine distribution is discussed in a later section (2.62 Description of P. merkusii Forest), but it is obvious that, for the stations charted, a tropical savanna type of climate is involved with a long dry season extending from October or November to May or June, during which period the deficit in soil moisture becomes pronounced.

Map 1 represents the moisture regions of Southeast Asia based on the map of Moisture Regions of Asia published in Carter and Mather (1966). From this it will be seen that the greater part of Thailand falls into the Subhumid Type. The mountains in the north and west, some parts of the Korat Plateau and the outliers of the Cardamom Range in the southeast, being wetter, come within the Humid classification.

2.3 Physiography and Geology

The natural landscape of Thailand comprises mountains, plains and plateaux. There are five major physiographic regions:

- (i) The western mountains, including peninsular Thailand. These mountains extend in a belt roughly parallel to the Burma border from the north of the country down into the peninsula and thence into Malaya in the south. Basically the mountains consist of a

series of high granite ridges up to about 2000 m, separated by relatively narrow valleys and orientated approximately north-south. The occurrence of limestone in parts disrupts the pattern to some extent.

- (ii) The northern mountains. According to Dobbie (1966) these comprise an intensely folded old mountain system of shales, schists and limestones in an advanced erosional stage and with their intrusive granite cores exposed in north-south lines. Some of the highest mountains in the country occur in this region with peaks over 2000 m.
- (iii) The Korat Plateau. This plateau tilts away from Central Thailand towards the Mekong. It averages about 150 m above sea level but the scarp reaches over 460 m in parts. Geologically the plateau is a practically horizontal bed of red sandstone, lying unconformably and relatively undisturbed upon the general mass of eroded and faulted rocks apparent at the surface in most adjoining areas. Drainage is by means of broad flat valleys separated by flat-topped interfluves. Extensive marshy flats are associated with large rivers such as the Nam Mun and the Nam Chi. Flooding in the Mekong causes seasonal back-flooding in the Nam Mun and hence inundation of extensive areas during the rains. For most of the year, however, the water table of the interfluves lies well below the surface.
- (iv) The Cardamom Mountains. These mountains are simply an extension in southeast Thailand of the main range of the Cardamom Chain across the border in Cambodia.
- (v) Central Thailand. Central Thailand is occupied by an extensive alluvial plain extending from Uttaradit down to the Gulf of Siam; it is bounded to the east by the scarp of the Korat Plateau and to the west by the north-south Tanon Tong Chai and Tenasserim ranges. It is over 400 kilometres long and varies in width from 50 to 100 km. The plain is both watered and drained by the Chao Phraya River and its main tributaries in the north, the Ping, Wang, Yom and Nan Rivers. The rise and fall of the waters in this river system is vital to rice production and hence to the national economy of the country.

2.4

Soils

The soils of much of southeast Asia have resulted from weathering without frost or extremes of temperature fluctuation and under hot, wet conditions with or without a marked dry season. As

noted in the consideration of climate, the greater part of Thailand does in fact experience a definite period of little or no rain annually and hence many of the soil series have developed under savanna conditions. Large areas of Thailand such as the Korat Plateau and the central plain are of low relief and have been thus for a considerable period. Very little rejuvenation or alteration of the soil mantle occurs unless low elevation and proximity to a river system results in deposition of alluvium. This is true also of some of the older, less steep land surfaces in the hilly regions to the north and west and no doubt applies equally to the soil caps on flat topped plateaux projecting above the general level of the land surface, as at Phu Kradoeng near Loei. Samapuddhi (1963) in discussing the soils of the Korat Plateau states that they suffer from "too little erosion".

The main soil associations of Thailand are shown on a 1 : 2,500,000 map produced in 1964 by the Thai Survey Department on the basis of data provided by the Rice Department and the Land Development Department (Anon, 1964a). Reference should be made to the paper by Dudal and Moormann (1964) for the definition and description of the major soils of southeast Asia. Virtually all the soil associations shown on the map are latosols, podsolics or gleis, the latter being associated with river alluvia, plains and low-lying coastal areas.

From the point of view of the occurrence of P. merkusii it would appear, from the work by the E. P. T. A. soils survey expert attached to the Soil Survey Division of the Land Development Department, that podsollic soils are of prime importance. The soil survey for the FAO pulpwood project carried out in the Srisaket area of Northeast Thailand (Omakupt, 1965) indicated that the pine forests were confined in the main to soils of the Korat and the Korat/Phon Phi Say series. The former series is composed of soils with a loamy sand to sandy loam topsoil becoming finer sandy loam to sandy clay loam in the subsoil. Surface layer pH is 5.5 - 6.5 but pH drops to 4.5 - 5.5 in the subsoil. Organic matter is usually about 1% in the grey-brown to light grey-brown surface soil. Mottling frequently occurs in the subsoil but may be absent altogether in the better drained higher profiles. This series is referable to the Grey Podsollic Soils at the great soil group level (Dudal and Moormann, 1964). The Korat/Phon Phi Say series is an association in which Korat soils dominate with Phon Phi Say soils occurring in patches, especially where the land has been slightly eroded, e. g. on slopes. Phon Phi Say soils are composed of sandy loam to loam in the top soil, passing to finer materials such as clay loam or clay with increasing depth. Lateritic gravels are found at less than 50 cms. depth, ordinarily in great quantities. In the clay subsoil, pH values are usually 4.5 - 5.5. Owing to the subsoil characteristics these soils have impeded drainage. In the rainy season they quickly become very

wet in the surface layers and more slowly so at depth. In the dry season very considerable drying occurs in the surface layers but the clay subsoil apparently remains moist for a long time.

Pines are absent from areas where the Phon Phi Say series is extensive but are frequent on the Korat/Phon Phi Say soil association. Due to the preponderance of soils of the Korat series the association presumably falls under the Grey Podsollic Group.

Soils of the Korat, Nam Phong and Yasothon series of grey, yellow and red podsolics are very widespread elsewhere on the Korat Plateau and it is assumed that the other pine stands in this region are found on these soils.

Grey/brown podsollic soils are also mapped on quartzitic and siliceous hills especially towards the scarp edges of the plateau and it is thought that the P. merkusii stands on the summit of such hills in the vicinity of Loei and between Loei and Petchabun are on these soils. A stand of P. merkusii (with some P. kesiya) was visited by me on Phu Kradoeng Plateau southeast of Loei. On part at least of the generally level and rather poorly drained plateau the soil appeared to be strongly podsollic in character.

Concerning the distribution of pines in the northwest, Masson (personal communication, 1967) states that the pine areas were found to coincide with red/yellow podsollic soils with a pH around 5.5 to 6.0. Pines were absent in that region from the Brown Earth soils which were characterised by hardwood stands. The P. merkusii seen by me along the Tak / Ban Mae Sot road was on pallid, grey, very rubbly soil which probably represented an old river terrace now elevated and very well drained.

It is probable, from a comparison of the map of soil associations (Anon, 1964a) and Critchfield and Little's distribution map of the pines of the world (1966), that the pines reported to the west of Phetburi (Masson, pers. comm. 1966) and Kanchanaburi (Mirov, 1967) are on podsollic soils as well.

On balance, therefore, the evidence in Thailand suggests a definite link between the natural occurrence of pine stands and podsollic soils. But such soils are very widespread in the country, especially in the northeast.

Forest Types

Thailand is essentially a forested country, although by reason of a long dry season, much of the forest is deciduous and rather open.

About 70% or approximately 360,000 square kilometres of the country is estimated to be covered by forest of one type or another (Anon, 1950). The following brief descriptions of the major forest types is based on the compilation by Krit Samapuddhi (1955).

2.51 Evergreen Forest

Evergreen forests are to be found at all elevations from sea level to the tops of the highest mountains and on many soil sites and soil types. They may be classified into four broad types:

- (i) Tropical evergreen
- (ii) Hill evergreen
- (iii) Mangrove forests
- (iv) Coniferous forests

(i) Tropical Evergreen: This type of forest is found throughout Thailand and reaches its greatest development in the southern and south-eastern parts of the country. It is rich in species, diversified in character and contains many timber trees of commercial importance, among which may be mentioned Dipterocarpus spp, Hopea odorata, Azalia spp., Shorea spp., Mesua ferrea, Artocarpus calophylla, Sandoricum indicum, and Cinnamomum spp.

(ii) Hill evergreen: Hill evergreen forest is characterized by the prevalence of Quercus and Castanopsis spp. which are almost always present and form an important part of the stand. These forests are usually limited in area and occur in mountainous regions at altitudes in excess of about 1000 metres, hence the main distribution of this type of forest is in northern Thailand. Although the timbers of several species found in this forest are durable and ornamental, only a few are listed by the timber trade, e. g. Schima spp., Michelia champaca and Heliocia robusta. Inaccessibility and prohibitive cost of extraction are the principal reasons for lack of exploitation.

(iii) Mangrove forests: The coastline of the country is over 2000 kilometres long, the greater part of which is occupied by Mangrove forests. The total area of this type of forest is computed at about 1620 square kilometres. The important species in these forests belong mostly to the specialized family Rhizophoraceae. Mangrove forests are of very great commercial value, being highly productive per unit area and easily accessible by water. Dye and tan-bark from these forests are also valuable and are well-known in the export trade.

(iv) Coniferous forests: The coniferous forests comprise two species of pines, Pinus kesiya and Pinus merkusii. The distribution of Pinus kesiya is confined to the hilly and mountainous parts of the country in

the northwest, northeast and north centre, at altitudes usually in excess of 1000 metres. The distribution and characteristics of Pinus merkusii forests are dealt with in section 2. 6.

In the past the economic importance of these forests has been the supply of resin for distillation into turpentine and rosin, the whole output of which is consumed in local industries. However, the coniferous forests are currently of considerable interest as possible sources of pulpwood.

2.52

Deciduous Forests

Deciduous forests both of mixed deciduous and deciduous Dipterocarp type are found throughout northern, central and northeastern Thailand. In the eastern part they occur sporadically but in the south are entirely absent. Deciduous forests are estimated to cover about 70% of the whole forested area of the country. These forests thrive on a variety of soil types and are not very selective as regards site and elevation. They are to be found on plains as well as on the hills but rarely ascend to an altitude over 1000 metres. They may be broadly divided into two types:

- (i) Mixed Deciduous
- (ii) Deciduous Dipterocarps

(i) Mixed Deciduous: The teak-bearing mixed deciduous forests are chiefly distributed in the northern part of the country and are composed mainly of deciduous species. As a type these forests are among the most valuable assets of the country. Teak and many other valuable timbers known in international trade are derived from them. Bamboos occur in great abundance in some and are an important article of local trade. Apart from timber these forests are a source of various minor forest produce such as fibre, crude drugs and food.

(ii) Deciduous Dipterocarps: These forests occupy vast tracts in the northern, central and northeastern parts of the country, covering about 45% of the total forest area. The general appearance is open with trees of medium size and height. The soil is generally gravelly, sandy or lateritic and has a profound influence on the composition of the forest. Usually the tree species are more or less mixed though pure associations, particularly of Pentacme siamensis, Shorea obtusa, Dipterocarpus tuberculatus, Dipterocarpus obtusifolius, and Dipterocarpus intricatus occur and are of good growth and development. These forests constitute an important resource and are the principal source of fuel, posts and heavy constructional timber for public, industrial and domestic use as well as for export.

2. 53

Other Types of Forest

Besides the principal types of forest already described there are minor types of little economic importance at present. Among these are:

(i) Beach Forests: These occur along the sea coasts on sandy beaches and are characterized by Casuarina equisetifolia, Calophyllum inophyllum, Pongamia glabra and Hibiscus tiliaceus.

(ii) Swamp Forests: These occur both in central and southern Thailand. The most common species are Hydnocarpus anthelmintica, Xanthophyllum glaucum, Lagerstroemia flos-reginae, Albizia procera, Butea frondosa and many species of Nauclea and Barringtonia.

Another type of swamp forest occurs on sandy ground near the sea coast where the soil is acid. In such forests Melaleuca leucadendron forms an almost pure crop.

2. 6

P. merkusii in Thailand

2. 61

Distribution

The distribution of Pinus merkusii in Thailand is dispersed, the species being found in a number of physiographic regions:

(i) to the northwest and southwest of Chiang Mai up to and across the Burma border and usually at altitudes between 700 and 1000 m (Burkill, 1924; Cooling, 1967; Mirov, 1967; Royal Forest Dept., 1950; Suvatabandhu, 1961; Udawn in Larsen, 1962)

(ii) between Tak and Ban Mae Sot in the mid-west

(iii) in the Bilauk Taung range near Kanchanaburi about 280 kilometres almost due west from Bangkok (Mirov, 1967) and a little further south on the same range to the west of Phetburi (Masson, pers. comm., 1966)

(iv) in several places in north-central Thailand, notably to the east of Phitsanulok towards Phetchaburi at about 760 metres elevation (Masson, pers. comm., 1966; Mirov, 1967), near Loei on Phu Kradoeng Plateau at 1500 m elevation (Bryde et al., 1965; Larsen, 1962; Premrasmi and Smitinand, 1960) and in the vicinity of Udon Thani (Masson, pers. comm. 1966)

(v) in the east of Thailand in the provinces of Surin, Srisaket and Ubon, usually at elevations of between 100 and 200 metres (Bryde et al., 1965; Royal Forest Dept., 1950)



Plate 2a.

P. merkusii in dry Dipterocarp forest near Baw Luang, Northwest Thailand.

D. b. h., 86 cms; height, 30 m; altitude, 900 m.

Note fire damage to base of tree.



Plate 2b.

P. merkusii dominating dry Dipterocarp forest (including *D. tuberculatus*) on road between Tak and Ban Mae Sot, Thailand.

D. b. h., 80 cms; height, 23 m; altitude 337 m.



Plate 3a.

P. merkusii in groups in semi-humid Dipterocarp forest,
Srisaket, Thailand.

D. b. h., 51 cms; height, 24 m; altitude, 130m.

(some clearing has been done along the track.)



Plate 3b.

P. merkusii in grassy glade in semi-humid Dipterocarp forest,
Srisaket, Thailand.

Altitude 130 m.

Maps 3 and 4 give the distribution of P. merkusii in Thailand, Laos, Cambodia, Vietnam and Sumatra. See also Critchfield and Little, 1966, for the geographical distribution of P. merkusii throughout its natural range.

The area of pine forest in Thailand has been variously estimated at a total of about 228,600 hectares (Premrasmi and Smitinand, 1960) and a net pine area of 28,000 hectares (Bryde et al., 1965). The latter estimate is stated to be conservative and is the area of well-stocked pine in the major tracts only. Small occurrences as at Tak and Kanchanaburi are not included.

2.62 Description of P. merkusii Forest Types

In Thailand P. merkusii is found in three main types of forest or habitat: (See Plates 2 and 3)

- (1) Mixed P. merkusii/dry Dipterocarp forest of the higher altitudes
750 - 1000 m
- (2) Mixed P. merkusii/hardwood forest at low altitudes up to 300 m
- (3) Pure or nearly pure P. merkusii on sandstone plateaux

2.621 Mixed P. merkusii/Dry Dipterocarp Forest

This type was studied in the vicinity of Baw Luang some 120 kilometres to the southwest of Chiang Mai and again on the road between Tak and Ban Mae Sot. It is believed to be typical of much of the P. merkusii forest in the north and northwest of the country and possibly also of the pine forests near Petchabun in north central Thailand.

Typically P. merkusii occurs as small groves and scattered individuals in a matrix of deciduous hardwoods, among which D. obtusifolius and D. tuberculatus often predominate. This forest has a dry open aspect, reminiscent of the central African 'Miombo' woodland. Grass and herb cover is moderate and there is much evidence of frequent fire.

Mature P. merkusii probably attains heights of 25 to 30 metres in this type of forest but this is difficult to determine because so much secondary growth with small trees is present as a consequence of shifting cultivation, exploitation and tapping for resin. The trend is for little disparity between the heights of pine and the taller hardwoods on the deeper soils but on dry, rubbly sites as along the Tak/Ban Mae Sot Road mature pines overtop the hardwood stands by several metres. Since the former are often most numerous on ridges and spurs they

are conspicuous emergents on the skyline.

In the Baw Luang region, P. merkusii with dry hardwoods occurs on podsolic soils from about 750 m up to some 1000 m in altitude. Between 1000 m and 1100 m an ecotone is found in which P. kesiya may also be present, either scattered or in groups, while at higher elevations P. merkusii and the dry Dipterocarps give way entirely to evergreen hill forest with or without P. kesiya. When present in hill forest P. kesiya occurs in small groups or in stands of varying size and only rarely as scattered individuals.

At first sight the relative distribution of the two pines appears to be controlled only by altitude. However, on the Baw Luang/Om Koi Road, for instance, several examples may be seen where the positions of P. merkusii and P. kesiya are inverted. The latter species is found at lower elevations in groups and in small stands among evergreen hill forest in the valley heads, whereas P. merkusii and deciduous Dipterocarps occupy the broader ridge tops and flatter interfluves above them, but under drier more exposed conditions.

Both pines seemed to be on podsolic soil, but the P. kesiya sites would experience some degree of rejuvenation and probably also lateral moisture seepage due to their topographic situation.

Between Baw Luang (1100 m and Mae Sariang (350 m) the motor road provides an interesting transect of the forests which range from evergreen hill forests with P. kesiya on the hill tops at Baw Luang, through an ecotone in which both pines occur, to P. merkusii/dry Dipterocarp at middle elevations and thence down to mixed deciduous forest with teak at Mae Sariang. P. merkusii was not actually seen associated with teak but comes very near to the teak-bearing forest in places. At any given altitude the type of soil plays an important role in the distribution of pines and hardwoods. The pattern is of pine mixed with Dipterocarps on the podsols which are red-yellow coloured with shallow topsoil, while hardwoods predominate on the deep-toned red and brown latosols, usually with deep topsoil. The usual pattern of altitudinal distribution is P. kesiya at the higher and P. merkusii at the lower elevations but edaphic conditions may locally cause inversion, especially in the vicinity of the ecotone. Aspect, too, may be important. Masson (pers. comm., 1967) considers that P. merkusii is not found lower than 750-800 m because podsols are absent below this elevation in the region.

P. merkusii was again encountered about 35 kilometres from Tak on the road to Ban Mae Sot. The altitude was only 337 m but this occurrence has strong affinities with the Baw Luang type although

representing a drier phase. The pine is found on gravelly ridges as small groups of emergents over poor quality dry deciduous Dipterocarp forest containing much D. tuberculatus. The soil is pallid, fine and admixed with gravel. Quartz rubble is evident on the surface and the site was presumed to be an old river terrace now elevated and incised, the pines occurring on the ridges and caps representing the older heavily leached surfaces. The forest is particularly poor and open in aspect, there being evidence of frequent and severe fire. Pine regeneration is very sparse and only manages to become established in rocky areas where the ground vegetation is too thin to burn strongly.

Data adequate for the preparation of climatic water balance diagrams are not available for Baw Luang the nearest station being Chiang Mai, which lies some 20 kilometres in a straight line to the northeast and at about 314 metres elevation. Chiang Mai is thus at a lower elevation than the P. merkusii stands near Baw Luang which lie in the main between 800 and 1000 metres altitude. Assuming that the rainfall does not differ greatly between the stations, and allowing for a decrease of some 3° to 4° C in mean temperature due to altitude, it is probable that the basic pattern of the water balance diagram for Chiang Mai applies also to Baw Luang but that a slight decrease in the intensity and duration of the period of moisture deficit would result. Owing to the considerably greater altitude, 1000 to 1500 metres, of many of the pure P. kesiya stands in the northeast a decrease of some 5° or 6° C in mean temperature (0.6C per 100 m elevation) could be expected and this, assuming the same or a somewhat greater rainfall due to increased cloud interception, would lead to a more pronounced decrease both in the duration and severity of the annual soil moisture deficit.

The water balance diagram for Ban Mae Sot at 210 m elevation is thought to be a reasonable approximation to conditions prevailing in the pine stands on the Tak/Ban Mae Sot Road. The difference in altitude is some 100 to 150 m. This is unlikely to have much effect if precipitation remains the same, which is assumed to be the case.

2. 622

Mixed P. merkusii/Hardwood Forests at Low Elevations

The pine groves in the extensive hardwood stands in the Srisaket area are representative of this type. Although the forest has been described (Omakupt, 1965) as dry deciduous it is certainly of much moister aspect than Type 1 above. P. merkusii is found singly or in small groups or stands among a variety of hardwoods, chiefly Dipterocarps and including D. intricatus, D. tuberculatus, Shorea obtusa, Pentacme siamensis and D. obtusifolius. The pines are among the dominants but seldom emerge far beyond the upper

hardwood canopy level. The forest is of a denser aspect than that in the north and west and it appears that the pine is dependent upon fairly large gaps for successful regeneration. The low altitude (130 m) flat terrain is subject to periodic water-logging or even occasional flooding (Smitinand, 1958) and the soil is podsolic and acid (Omakupt, 1965). Ground flora is relatively sparse under the forest canopy but thickens considerably in gaps. Most of the forest seen had reached maturity, and canopy height, at 25 to 30 m, was considerably better on average than in the mainly secondary re-growth in the northeast. The water balance diagram for Maung Ubon, Fig. 1, is considered to be a very close representation of the conditions in the pine stands near Srisaket and in the southeast generally.

2. 623

P. merkusii Forest on Sandstone Plateaux

The pine stands on Phu Kradoeng plateau (1500 m. a. s. l.) near Loei, which bear a strong resemblance to the P. merkusii forests on Kirirom Plateau, Cambodia, are taken as representative of this type in Thailand. On Phu Kradoeng extensive but open fire-damaged stands occur in which P. merkusii is the sole dominant. Imperata is conspicuous in dense but only moderately tall grass cover. In parts of the pine stands suffrutex oak, apparently cut back annually by fire, is present in large numbers in the grass. Dense semi-evergreen gallery forest flanks some parts of the water courses and there is an occasional grove of Castanopsis spp. in depressions. An interesting discovery was a small but nearly pure stand of P. kesiya, the occurrence of which could not readily be justified on edaphic considerations. The collection of P. kesiya by Udawn on Phu Kradoeng in 1958 is reported by Larsen (1962). The ubiquitous Dipterocarps though present on the plateau flanks were virtually absent from the pine stands. This may be an altitudinal effect since Smitinand (1958) states that it is very rare for the genus to occur above 1000 m altitude in Thailand. The very open stands, frequent evidence of fire damage to standing trees and paucity of regeneration suggest that this pine forest has been deteriorating in condition for many years.

The soil was podsolic in character in the pine area and poorly drained in parts, although the parent material is almost certainly sandstone. The flat topography of the summit, coupled with enhanced rainfall and cloud due to altitude results in seasonally wet conditions. Drainage is by meandering stream. Acid and probably poor soil predominates, though the restricted areas of hardwoods may be indicative of areas richer in bases.

The nearest station to Phu Kradoeng for which a water balance

diagram (Fig. 1) could be compiled is Udon Thani. Owing to the considerable difference in altitude this is likely to overstress the duration and severity of moisture deficit and to show too little precipitation. There are, however, no grounds for assuming any radical difference in overall pattern of the water balance.

2. 63

Growth Habits

In Thailand P. merkusii is often impressive in size and straightness of bole in comparison with associated hardwoods and in relation to the poor site conditions under which it is frequently found. Where P. merkusii and P. kesiya occur in proximity the former attains the larger dimensions and is also straighter.

2. 631

Size under Typical Conditions

Mature P. merkusii is usually about 30 m in height and attains diameters in excess of 75 cms. In the Baw Luang area, where the forest has been subjected to much anthropic interference, several trees of 27 to 30 m in height and 65 to 90 cms diameter were measured. These were predominants or emergents over dry Dipterocarp forest. Secondary growth following cultivation was frequent and contained many pines with heights up to 20 m and diameters up to 50 cm. On a dry rubbly site on the Tak/Ban Mae Sot road an occasional large tree measured 23 m and 84 cms. d.b.h. but the average was considerably less, to the order of 20 m and 45 cms. Again P. merkusii dominated the dry deciduous hardwoods.

In north-central Thailand large over-mature individuals are a feature in the Phitsanulok pine area where many stems have a volume of 10 to 15 cubic metres, clean boles of 20 to 35 m and total heights of 45 to 50 m (pers. comm., Masson, 1967).

The low altitude pines on the Korat plateau growing in groves among hardwoods are usually some 25 to 35 m tall with diameters of 63 to 88 cms.

2. 632

Crown Shape and Branching

Young P. merkusii almost invariably has a pyramidal crown form in youth with well-developed apical dominance once the grass stage has been passed. It later attains a flatter and more spreading crown. In Thailand this pine is strongly uninodal, averaging one whorl of branches per year. Occasional "foxtail" trees are seen in pole stage growth and in such cases several years may pass without the development of a whorl of normal branches, though occasional very

short malformed branches may be produced. Foxtail trees are characterized by the retention of needles on the bole which may be profusely covered.

A check on the relationship between the number of growth rings and whorls gave the following results:

Table 1

Relationship between numbers of branch whorls and growth rings in Thailand

Locality	Tree No.	No. of Growth Rings at 30 cms above ground level	No. of Branch Whorls above 30 cms	D.B.H. in cms	Diam. at 30 cms	Total height in metres
<u>Srisaket</u>	343	14	14	12.5	14.5	10.1
	344	18	15	12.7	14.5	12.8
	345	15	16	10.2	11.4	9.7
	346	17	18	18.2	19.0	15.2
	347	13 or 14	10 + 2	11.2	13.2	10.6
	Totals	77.5	75			58.4
	Arith. Mean	15.5	15			11.7
<u>Phu Kradoeng</u>	374	20	18	19.5	-	11.0
	375	26 or 27	25	23.0	-	13.4
	376	20	19	19.5	-	13.1
	377	24	25	20.0	-	15.2
	378	24	23	23.7	-	11.0
	Totals	114.5	110			63.7
	Arith. Mean	22.9	22			12.7

The uninodal habit is clearly demonstrated at both localities: no single tree displays a marked divergence from the pattern. On the basis of arithmetic mean numbers of rings (age) and the mean height of the pine trees at each locality, average annual internode length (height increment) is, respectively, 78 cms and 55 cms.

2. 633

Bark

All P. merkusii examined by me in Thailand had thick bark (usually to the order of 6 cms at breast height) on mature trees. The bark is dark brown to ashey grey in colour, and usually vertically ridged, having occasional horizontal fissures. Some trees show a reticulate pattern of bark cracking. There is no doubt that the exceptionally thick bark confers a marked degree of fire resistance on this species. Although not established with certainty, it is considered likely that the reticulate bark pattern reflects exposure to frequent and severe fire. This hypothesis is supported by the fact that trees may be found with both types of bark on the lower bole, the reticulate pattern being in the position of greatest exposure to fire damage. Masson (pers. comm., 1967) considers that differences in bark characteristics observed by him in Thailand may indicate the existence of varieties or races of P. merkusii but more work is required to establish this. He reports for instance that there appear to be two strains of P. merkusii in the east, in the vicinity of Srisaket; one with thick deeply fissured bark and prominent persistent branches which arise at approximately right angles to the stem, while the other has finer less persistent branches arising at a more acute angle to the stem and thinner, less deeply fissured bark, if P. merkusii can be said to have a thin bark when the bark percentage is approximately 15% to 20%.

2. 634

Root System

Few opportunities presented themselves for a study of P. merkusii root systems but the impression was gained that the species is firmly and deeply anchored by a combination of far-ranging and relatively superficial roots, plus one or more deep taproots.

2. 635

Cones and Male Flowers

In all the Thai provenances seen cones are borne singly, or in twos and threes and project very characteristically at right angles to the branch of attachment. Female cones are most frequent in the upper third of the crown towards the ends of exposed laterals and on the leader itself. The majority of cones ripen in the period April - June, though all cones in a single cluster may not ripen at the same time. Tree to tree variation in stage of ripeness is fairly marked, and good seed years are said to alternate with poor ones. Cones are shed soon after releasing the last of the ripe seed, and are not persistent on the tree as is the case with P. kesiya. Male flowers are borne in clusters or spikes on branchlets in proximity to the female cones and also lower in the crown. Full-sized open cones measure about



Plate 4a.

P. merkusii and *D. tuberculatus* regeneration in mixed pine/dry Dipterocarp forest near Baw Luang, 900m, Northwest Thailand.



Plate 4b.

P. merkusii regeneration in open grassy glade in semi-humid Dipterocarp forest, Srisaket, 130 m, Thailand.
(approximately 60 plants in circle of 14 m radius.)

6-8 cms, exceptionally 9 cms in length by 5.5 - 6.5 cms in width.

2. 636

Seed

P. merkusii seed from the lowland provenance at Srisaket averages 24 to 25 grams per 1000 seeds or 40, 700 per kilo (18, 500 seeds per lb.). The upland provenance from Baw Luang averages 35 to 36 grams per 1000 seeds or 28, 200 per kilo (12, 800 seeds per lb.) Two winged seeds are borne at the base of each well-developed cone-scale. Cleaned Baw Luang seeds average about 7.5 mm long by 4.0 mm wide and being flattened in cross section, 2.0 - 2.5 mm thick. Seeds are usually mottled fawn and black but some are uniformly light in colour. The seed wings are unequal-sided and about 30 mm by 8 mm wide. They are attached to the seed by basal hooks connected to hygroscopic tissue in the base of the wings, with the result that the seed is firmly held during dry conditions favouring wind dispersal, but is quickly released when moist conditions suitable for germination are encountered. Phu Kradoeng seeds are about the same size as those from Baw Luang, but Srisaket seed is smaller.

Germination capacity of seed is high shortly after collection but it rapidly drops with storage to exceptionally low values for pine seed. Batches of seed sent overseas from Thailand often give a germination of less than 10%, whereas P. kesiya seed from the same area and handled in the same way seldom falls below 65%. High moisture content may be one of the factors involved but there is plainly an urgent need to investigate the physiology and storage requirements of P. merkusii seed, the more so because similar difficulty has been experienced with seed from Cambodia and Vietnam.

2. 64

Regeneration

2. 641

Natural Regeneration (See Plate 4)

Natural regeneration, though often sparse, was present in each of the pine areas visited. The seedlings of all P. merkusii provenances seen in Thailand have a characteristic grass stage during which very little height growth is made while the plant develops a really thick almost carrot-like stem, most of the diameter of which is represented by secondary cortex. The short thick stem carries densely-packed long, stout needles which are tufted at the apex and completely obscure the bud. In the field, such a plant closely resembles a tuft of grass. Individual plants remain in the grass stage for varying lengths of time but it is unusual for any significant height growth to be made earlier than the third to fifth year. There is evidence that plants in favourable growing conditions and in the absence of fire stay in the

grass stage for a shorter period than those less favourably placed.

In the upland forests at Baw Luang natural seedlings were encountered throughout the pine area but it was clear that shifting cultivation and frequent fires were taking a serious toll. Seedlings were particularly numerous where mineral soil was exposed, as for example along old extraction paths, eroded slopes and road verges. This was probably due in part to reduced competition with grass but was considered to be largely a reflection of decreased exposure to fire. A characteristic of the mixed pine/deciduous dipterocarp forests is the ability of the pines and hardwoods to grow in intimate mixture at all stages of development from seedling to adult tree, though, at maturity, the pines tend to dominate in terms of height and crown spread. In this forest type, probably on account of its open character, regeneration is not dependent on large clearings, but a definite gap in the canopy does stimulate establishment. Seedlings are often numerous in bare patches in the ground vegetation caused by fierce fire but are unlikely to survive for long once the ground flora sprouts again and creates a fresh fire hazard.

Under the extremely harsh conditions in the pine area along the Tak/Ban Mae Sot road regeneration was poor. Although there were numerous current season's seedlings scattered throughout the area the only established seedlings were on rocky knolls or patches of dense surface gravel where the severity of fire would be greatly diminished. In this locality, with a long period of soil moisture deficit and high mean temperature, the additional adversity of annual fire was evidently more than even the fire-hardy pines could withstand. The paucity of regeneration and much evidence of serious fire damage to standing trees indicates that this forest is in a phase of retrogression.

Regeneration in the low altitude pine/hardwood forest as at Srisaket, for example, is far more dependent on gaps and openings in the canopy than is the case in the northeast in the more open and drier formations. Good regeneration in various stages of establishment was observed near Srisaket but virtually all was associated with openings of one sort or another, e. g. along path and road edges, on the forest edge against open grassland or in gaps within the forest itself. This dependence on clearings is probably due to the taller and denser hardwood stands and results in more or less even-aged groups or ribbons of pines in a general matrix of hardwood forest. It has been pointed out in the discussion on soils (Section 2.4) that pine is confined to the more acid, podsollic soils. On more favourable sites establishment would probably not be possible in the face of competition by hardwoods. The most favourable site of all for establishment appeared to be a recent gap in the canopy of a group of pines. In these circumstances

the seedlings are able to develop on a relatively clean, needle-covered floor under conditions of adequate light and reduced root competition. A minimum width of about 10 to 14 metres seemed necessary to ensure good establishment. In one opening some 14 metres in diameter 60 healthy plants in various stages of development were counted. Again, the frequency of fire and the cycles of cultivation were seen to play a decisive role in the success or otherwise of pine regeneration.

The rather special conditions of the forest on Phu Kradoeng plateau, that is, a very open grassy pine wood with little or no competition from hardwoods, would seem ideal for pine regeneration but it is, in fact, disappointing. A study of established regeneration indicates that groups of seedlings have managed to get away here and there to form more or less even-aged small stands. There is a strong probability that such groups represent areas that escaped fire for the first two or three years of the seedlings' development. That the area is subject to frequent, probably annual, fire over the major part is evident from the state of Quercus regrowth. This is burnt back annually and has assumed suffrutex form.

It is clear from the foregoing that satisfactory regeneration requires relatively open conditions. These are achieved under the usually light canopy of the dry deciduous forest of the hills or in gaps in the generally heavier canopy of the moister Dipterocarp forest of lower altitudes. Clearing for cultivation and the opening up of forest canopy by exploitation or periodic fire works to the advantage of the pine, which readily establishes under such conditions. However, if fire becomes annual, and ground vegetation or litter is dense enough for a strong burn, regeneration is greatly impeded. Under such conditions, as at Tak, establishment is possible only in isolated spots protected from fire. Grass, including Imperata unless excessively dense does not preclude seedling establishment but may decrease survival and reduce growth rate. Increased fire hazard in dense grass is the more serious aspect.

The cause of the fires was not established. There are no shifting cultivators on the plateau itself but fires started on the plains might sweep up the scarps to the summit. As the plateau is a Nature Reserve hunters are not a likely cause, but, in view of the topography, lightning might play an important role.

2. 642

Artificial Regeneration

No large-scale artificial regeneration of P. merkusii was seen in Thailand but at the Pine Forest Experiment Station near Srisaket

the species was being raised experimentally.

Seed was sown in prepared nursery beds during October. The seedlings were pricked out when some 8 cms high into plastic bags 15 cms tall and about 7.5 cms in diameter. Planting is done in July when the plants are about 20 cms tall.

Seed beds were previously shaded with palm fronds but now plastic mesh is being tried and appears to be satisfactory. The nursery soil is obtained from the nearby pine forest but is heat-sterilised. Soil is mixed with rice husks in the proportion of two parts soil to one of rice husk, because the local soil is fine and becomes compacted in containers. Fertilizer is incorporated into the soil mix at the rate of 3 tins (about 700 gms) of NPK 8:12:8 fertilizer to 400 litres of soil.

During February to May transplant losses occur. This is locally believed to be due to excessive heat but watering pattern could also be involved.

Plants are graded monthly and the best developed are planted first. It is found that growth in the nursery accelerates with the onset of rains in May and also evens out.

Planting is done into small prepared spots in felled but not stumped forest land. Tending comprises cultivation as necessary for two or three months followed by slashing until the plants are well established. Good weeding is found to shorten the grass stage.

P. merkusii seedlings and transplants were also seen in the forest nursery at Baw Luang. The main species being raised is P. kesiya; P. merkusii formed only a small proportion of the stock.

Seed is sown from October to January but October sowing is preferred as this produces a 20 cm plant by the beginning of the rains.

Nursery soil is a mixture of two parts forest loam to one part of sand and no trouble is experienced through lack of mycorrhiza as the nursery is in the midst of pine/hardwood forest with both pine species present.

Seedlings are pricked out 15 to 20 days after germinating just as they shed the seed coats from the tips of the cotyledons. The same soil mix is used in the plastic transplant bags (18 cms high x 10 cms diameter) as in the seed beds.

Some losses are experienced from damping off but this is not considered serious. Dense sowing has been found to increase the incidence of damping off while sandy soil and well spaced plants decrease losses.

The P. merkusii seedlings seen all exhibited a very pronounced grass stage. Transplant growth is very uneven though frequent moving leads to a more uniform crop, presumably by preventing the precocious plants from rooting into the soil beneath.

Some direct sowing into plastic bags is also carried out, usually at the rate of two to three seeds per bag.

Plants in the Baw Luang nursery are shaded by branches affixed to a high frame. This is done with the first sowing and the initially dense shade decreases as the seedlings develop owing to the drying out and progressive shedding of leaves. The fallen leaves have constantly to be removed from the pots but otherwise the method was successful.

2. 65

Silvicultural Treatment

No P. merkusii forest under intensive management was seen in Thailand and therefore this discussion relates to the silvicultural characteristics of the natural forest with or without some degree of protection.

The species is capable of surprising growth in terms of ultimate dimensions even on poor, dry sites. Rate of growth and productivity are another matter and will be considered in a subsequent section. It is very evidently a fire-tolerant species once established and appears to equal the very hardy Dipterocarpus obtusifolius (Troup, 1921) in this respect.

Large emergent pine trees by virtue of their size and great thickness of bark are relatively immune to fire damage and tend to be avoided by shifting cultivators. In consequence there is a marked tendency for mature and over-mature trees to predominate in the P. merkusii areas which have become subject to increased fire and cultivation because both result in greater damage to the younger age classes. Silvicultural improvement of such forest would call for the exploitation of mature and over-mature trees, reservation of adequate seed bearers in the middle age classes and fire protection or, more realistically, controlled burning. Protective early burning should offer an economically feasible means of increasing the amount of regeneration in selected areas. The main requirements would appear to be:

- (i) a strong fire in the area to be regenerated in a given year, aimed at exposing mineral soil and timed to precede seed fall
- (ii) an attempt to exclude fire from the regeneration area for two to four years while the seedlings develop their protective thick bark
- (iii) early burning annually throughout the remainder of the pine area carried out early enough in the dry season to preclude a fire developing on a wide front; a patch burn of only the drier, more inflammable material being the aim. Such burns would be repeated if necessary as more vegetation died down until there was reasonable assurance that no uncontrolled fire later in the dry season could sweep through the area at strong intensity on a wide front

An interesting pair of regeneration plots was visited in natural P. merkusii forest at Srisaket. One treatment consists of burning off the ground vegetation, scarifying the soil in May prior to the peak seed fall, which occurs in June-July, and thereafter applying strict fire control until regeneration is established. The second treatment, intended as a control, involves no burning or scarification prior to seed fall but complete protection thereafter. These treatments were said to be repeated in three different parts of the forest. The results of these trials should be most valuable when they become available in a few years' time.

Rate of Growth

Few comparative data are available in this respect. In a report on the pine resources of Thailand the Nordic Group (Bryde et al., 1965) investigating pulp and paper prospects state that "an annual growth rate of even 5 to 6 cubic metres per hectare does not apply to the existing stands in the Mekong Basin which must in fact be considered entirely unproductive as they appear today". Masson working on the FAO/UNDP paper and pulp materials survey in Thailand stated in a personal communication to the writer that much of the growing stock is over-mature with large diameters and long clean boles. A number of increment cores were taken by me during the course of this tour and results are tabulated overleaf. These confirm the foregoing conclusions.

TABLE 2.

MEAN ANNUAL DIAMETER INCREMENT DETERMINED ON 4 mm. CORES

Origin	Tree No.	No. of Rings	Width (mm)	Running total (mm)	Mean annual diameter increment per section (cms)	Mean annual diameter increment full core (cms)	Remarks
Phu Kradoeng Plateau, Thailand	T374	0-20	74.25	74.25	.74		Reading from pith to bark
	T375	0-20	70.44	70.44	.70	.68	
		21-25	14.25	84.69	.57		
	T376	0-20	67.82	67.82	.68	.66	"
		21-23	8.03	75.85	.535		
	T377	0-20	66.85	66.85	.67	.63	"
		21-25	11.76	78.61	.470		
	T378	0-21	70.0	70.0	.67	.67	"
	T379	0-20	18.70	18.7	.19	.20	Reading from bark inwards. Core difficult to read. At least 50 rings considered false. Core represents $\pm 1/3$ total tree radius
		21-40	21.15	39.85	.21		
		41-60	21.00	60.85	.21		
		61-80	20.45	81.30	.20		
		81-100	20.00	101.30	.20		
		101-120	17.5	118.80	.17		
		121-140	20.00	138.80	.20		
		141-143	3.94	142.74	.26		

It is noteworthy, however, that the younger stems show an appreciably faster diameter increment than the older trees despite widespread fire and a good deal of resin tapping, both of which factors must reduce increment.

In plantations it would seem reasonable to expect average increments equivalent to the maximum recorded in the natural forest. This would mean something to the order of 1 to 2 m per annum in height and 0.7 to 1.0 cms diameter increment once the grass stage had been passed. This confirms the opinion expressed by Bryde et al. (1965) that after a few years of modest growth trees grown in plantations in Thailand could be expected to put on 2 to 3 m in height per year and to add heavily to diameter, at least until the age of 12 to 15 years, after which the growth would gradually slacken.

In Zambia P. merkusii of Burmese origin has been found to put on some 1.5 m in height and about 1.5 cms in diameter per annum once the grass stage is over.

2. 67 Injuries and Protection

2. 671 Fire

P. merkusii is well adapted to withstand fire at all stages of growth.

The grass-stage seedlings have the growing point effectively insulated within a dense tuft of stout needles and the seedling bark is remarkably thick, often as much as 0.75 cm in a plant no more than 20 cms tall. The erect growth habit also reduces the likelihood of the leader being killed by fire as would happen if the tip were to bend away from the vertical and become exposed to the flames at an angle. Despite this hardiness the amount of established regeneration is drastically reduced in areas where annual firing has become established (cf. 2. 641 Natural Regeneration). This situation, unfortunately, appears to prevail in most pine areas.

The thickness of P. merkusii bark in all size classes is remarkable ; mature trees with basal bark some 10 cms thick and with tall clear boles are virtually immune from all save the most severe ground fires. However fire damage to the base of large trees is relatively frequent. It is usually due either to smaller trees and large branches falling against the base of standing trees then catching fire and thus inflicting a deep scar which is extended in subsequent fires until the affected tree falls; or else to resin tapping without adequate precautions against fire.

2. 672

Shifting Cultivation

Shifting cultivation is widely practised in Thailand and indeed throughout Southeast Asia on soils other than the delta and plains alluvia capable of irrigation and the practice of more permanent forms of agriculture. As long as the intensity of cultivation is not great and the cycles of cutting are sufficiently spaced to permit regrowth to reach maturity or at least full seed-bearing age, the effect of this practice is advantageous to the spread of pine. The situation changes with increased intensity of cultivation due to the shorter cycles and concurrent increase in frequency of fires. Under these circumstances the pine forest is reduced to scattered over-mature emergents in various stages of senescence and then eliminated. Masson (pers. comm., 1967) has commented upon the very abnormal age-class distribution in the north and ascribes the dearth of the younger classes to the introduction of shifting cultivation into the pine areas at the beginning of the century plus subsequent increased occurrence of fire.

Premrasmi and Smitinand (1960) note that under the Forest Act pine is protected by law and permission must be obtained to fell it. In addition, the Forest Department is attempting to bring all pine forests under the Forest Protection and Reservation Act. In the opinion of these authors the pace of these operations is not in keeping with the present urgency and rapidly changing events, and in consequence there is "frequent clearing of forests for shifting cultivation and encroachment on pine forest lands". They further state "Danger from forest fires when compared with the above is indeed little because our forest fires happen on the ground and do not start in the crowns of trees..."

2. 673

Grazing

No data are available concerning the effect of grazing on P. merkusii stands. Observations in the northwest of Thailand and again near Srisaket suggest that the effect is a little complex. Grazing is likely to be a factor of significance in relatively well populated areas where the fire hazard is considerable. To the extent that grazing reduces the severity of fire by decreasing the amount of inflammable material it is probably beneficial to pine survival but the loss of seedlings through trampling may become excessive in heavily grazed areas. This risk is enhanced by the slow initial growth of the Thai provenance of P. merkusii during its grass stage.

2. 674

Wind

Under conditions in Thailand P. merkusii appears to be a wind firm species, a conclusion supported by the nature of the root system.

Because this species typically occurs at relatively low altitudes and since Thailand is not very subject to typhoons this provenance will seldom be exposed to great wind stress. On the other hand it is frequently an emergent on ridges and may grow in pure stands on exposed plateaux; in neither situation was wind throw observed without associated fire damage to the base of the tree. Trees with serious fire damage to the base are, however, quite frequently blown over by wind.

2. 675

Insect Pests

In the course of seed collecting some evidence of damage to green cones by an unidentified boring insect was noticed. There was also considerable evidence of borer damage in the dead and dying relics in degraded forest but no instance of attack on vigorous trees was observed. In this respect the contrast between P. merkusii and P. kesiya in the Baw Luang region was notable. The latter species was prone to shoot borer damage even in the natural stands whereas no evidence of similar attack was seen on the P. merkusii growing in the same area, either in mixture with P. kesiya or on its own. A plantation of young P. kesiya at Baw Luang was particularly heavily infected by shoot borers and specimens from this locality have been identified by the Lepidopterist at the Commonwealth Institute of Entomology as follows:

Pyralidae

Dioryctria sylvestrella Ratz (splendidella H. - S.)
Dioryctria abietella H. - S. sensu latu, possibly
f. mutatella Fuchs.

Tortricidae

Rhyacionia cristata Wals.

Gelechiidae

? Recurvaria sp.

Should afforestation with P. merkusii be undertaken it will obviously be necessary to keep a careful watch for the possible appearance of these pests so that their identity may be checked and control measures instituted.

No evidence of defoliation by leaf eating insects was obtained.

2. 676

Fungi

No information is available in connection with the prevalence or significance of fungus damage but my observations suggest that it is not an important factor in trees not already damaged by another agency.

2. 68

Wood Properties and Uses

Little information is available regarding the properties and uses of pine timber in Thailand. This is no doubt due, in part, to the availability of a wide range of hardwood timbers, including valuable and versatile woods such as Teak and Dipterocarp. Samapuddhi (1955) states that the value of the pine forests lies not in the supply of timber but in the supply of resin for distillation. This is confirmed by Premrasmi and Smitinand (1960), who note however that pine gave good results in experimental manufacture of plywood. They also point to the potential importance of long-fibred pine as a future raw material for paper pulp. This aspect is being investigated by an FAO/UNDP survey team and has been reported upon in the wider context of pulp supplies in the Mekong Basin by the Nordic Group participating in a co-ordinated investigation of the potentialities for the development of large-scale pulp and paper industry in the region, (Bryde et al., 1965). The Nordic Group report that very little is known of the pulping characteristics of P. merkusii. Its density is found to be about 13% greater than that of P. kesiya, which means that the pulp yield per cube will be proportionately higher. The wood density of both pines is higher than that of Scandinavian pulp wood. The specific gravity on an oven-dry basis of P. merkusii from Kompong Thom, Cambodia is quoted in the report as being 0.541. According to these authors the high resin content and somewhat darker colour of P. merkusii may be objectionable for mechanical pulping but the wood is less dark than certain American species used for grinding. The report concludes with a tabular statement of paper making and other tests carried out on a wide range of species besides P. merkusii (Samples No. 21 and 43).

Density determinations (saturated volume/oven dry weight) carried out on 4 mm increment cores collected by me at Srisaket gave the following values:

1. 4 young trees, 10-12 cm d.b.h.: Av. density 0.448
Range 0.403-0.536
2. 3 older trees, 33-35 cm d.b.h.: Av. density 0.507
Range 0.463-0.566

2. 69

Oleoresin

P. merkusii is an excellent source of oleoresin and is tapped even in remote areas. Samapuddhi (1955) states that departmentally controlled tapping is carried out in three forests; one in Srisaket Province, one in Petchabun and one in Ubol. Production figures for 1954 are given as:

Crude resin	109, 476 Kg.
Turpentine	16, 569 "
Rosin	76, 824 "

The demand by industry is not yet fully satisfied by local production and the deficit has to be imported.

There is also a good deal of uncontrolled tapping by local villagers in forest areas not under strict supervision. Much of this is very destructive in nature since a 'well' is often cut into the stem itself and precautions against fire are inadequate.

2. 70

Seed Availability

Although small quantities of pine seed have kindly been made available for experimental purposes by the Royal Thai Forest Department, Bangkok, it has been impossible to obtain larger quantities for pilot planting. The testing of a full range of the various Thai provenances has also not been possible owing to lack of seed or to very poor germination. A major problem is the dispersed distribution of the species throughout Thailand, often in remote and inaccessible areas. The preponderance of over-mature trees with large diameter long clean boles adds to the difficulty.

In view of this a seed-collection unit has been set up with the assistance of the UNDP (SF)/FAO Project concerned with the survey of pulp and paper material in Thailand. Tree-climbing equipment has been obtained and plans have been made for the selection and documentation of seed sources. Facilities for cold storage of seed are available at the Forest Department Headquarters in Bangkok. These developments should greatly improve the position regarding seed supply but first priority will no doubt be given to local requirements which may increase substantially if pine afforestation expands.

It is believed that consideration is currently being given to the possibility of implementing the recommendation by the Nordic Group (Bryde et al., 1965, p. 63) that a modern seed station be set up if plantations of pines are to be established to meet the projected needs

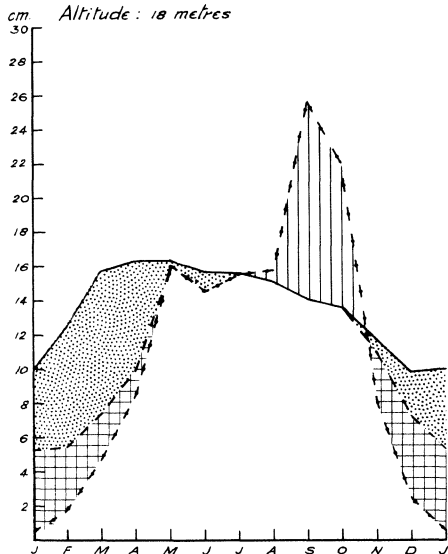
in pulp material. Tree breeding and improvement on the lines of the work already being done at the Teak Improvement Centre at Ngao in Thailand might well be included in the scope of the Centre. Keiding has recently (1968) investigated the question of establishing plantations in tropical climates with special reference to Thailand and has discussed the necessary integration of site selection, species trials, seed procurement and tree breeding and improvement in an unpublished report.

Reference was made in paragraph 2.636 to the very poor germination of most batches of P. merkusii seed exported from Thailand and also from neighbouring countries. This is a very important barrier to the introduction of this potentially valuable species to countries overseas and may hamper the testing of different strains within the country of origin as well as preventing the accumulation of big stocks of seed for large-scale afforestation. This problem merits thorough investigation.

FIG2. WATER BALANCE DIAGRAMS: CAMBODIA.

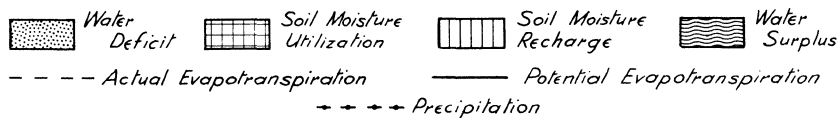
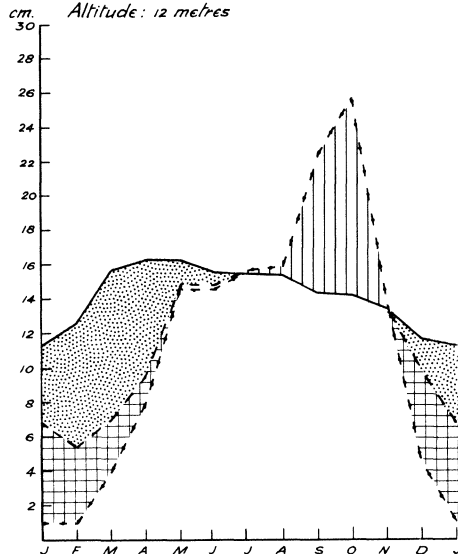
BATTEMBANG, CAMBODIA

Location: 13°05'N, 103°15'E
Altitude: 18 metres



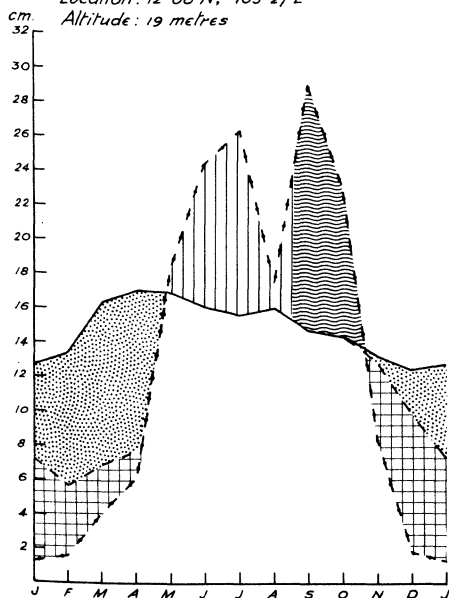
PHNOM PENH, CAMBODIA

Location: 11°33'N, 104°55'E
Altitude: 12 metres



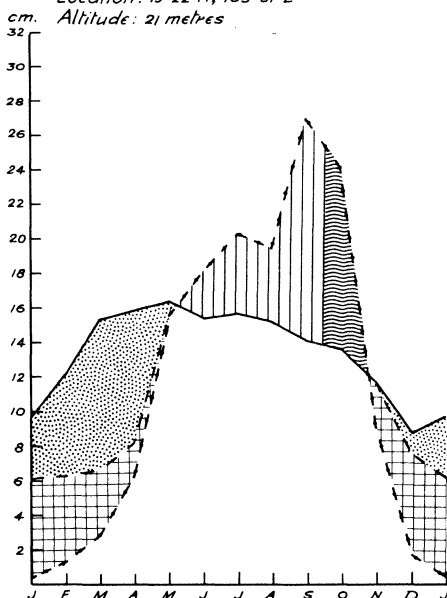
KOMPONG CHAM, CAMBODIA

Location: 12°00'N, 105°27'E
Altitude: 19 metres



SIEM REAP, CAMBODIA

Location: 13°22'N, 103°51'E
Altitude: 21 metres



CAMBODIA

3.0

3.1

General

The total area of Cambodia is somewhat less than 181,000 square kilometres. It is bordered on the west by Thailand, on the north by Laos and Thailand, on the east by Vietnam, while the Gulf of Thailand lies to the south.

The bulk of the population is confined to the flat alluvial plains which are well suited to intensive agriculture. Rice cultivation is highly important but animal husbandry, chiefly cattle, buffalo, pigs and poultry is also a major activity. The cultivation of rubber, pepper, sugar and other crops is of increasing value to the economy. The Great Lake and the Mekong are of first importance for the supply of fish. The timber resources of the country, chiefly hardwoods (but including the pines on the Kirirom Plateau) are being utilised and investigated on an increasing scale.

3.2

Climate

Cambodia has a tropical climate divided into three seasons - hot, March-May; wet, June-October; cool, November-February.

As in Thailand, the monsoon rains come on the southwesterly winds which predominate in summer. However, owing to the location of the coastal mountains, the Elephant Chain and the Cardamoms, much of the rain is intercepted resulting in very high precipitation on seaward mountain slopes and a relatively dry interior in the region of the Tonlé Sap and the lower Mekong plain.

Rainfall of 4000 mm or more is experienced on parts of the coastal mountain range. At Bokor, a hill station situated at 1050 m altitude on a ridge abutting the south coast, precipitation has averaged 4644 mm delivered over 170 days during a 22 year period (Setten, pers. comm. 1967). The average for stations in the drier interior is much lower. Phnom Penh 1412 mm, Kompong Thom 1623 mm, Siem Reap 1463 mm, and Battambang 1350 mm being typical examples. Long term data regarding precipitation on the Kirirom Plateau are not available but figures compiled by Setten from two sources and covering broken periods of the years 1944 to 1965 indicate an average of some 1800 mm. This compares with an average 2939 mm over 111 days of the year at Sre Ambell some 40 kilometres to the southwest of Kirirom and 1205 mm on 105 days per year at Kompong Speu approximately 50 kilometres to the east. Sre Ambell, although at relatively low altitude,

is on the seaward side of the mountains whereas Kompong Speu is in the rain shadow.

Precipitation is usually in showers, sometimes torrential but normally of relatively short duration. Lighter more persistent rain falls in the mountains in addition to storms. The whole country experiences average monthly temperatures in excess of 25.6°C even in the cool season. In April, the hottest month, the temperature averages 29.4°C in the flat central Tonlé Sap region and 26.7°C or slightly less elsewhere.

The prevailing wind directions are northeast during the dry season from November to March; from April to October the prevailing wind is southwesterly bringing in summer monsoon rains. During October the wind direction is very variable as the change from southwesterlies to northeasterlies occurs.

The climatic water balance diagrams for stations in Cambodia representative of the plains associated with the Tonlé Sap and the lower Mekong, Fig. 2, illustrate the high rate of potential evapotranspiration and the existence of marked seasonal moisture deficit for a significant period - about five months - each year. Adequate data are not available for a similar diagram to be made for the Kirirom Plateau but the higher precipitation, cooler temperatures and increased cloudiness due to its higher altitude and physiography should reduce, though not eliminate, the moisture deficit.

It will be seen from the Map of Moisture Regions in Southeast Asia (Map 1) that, apart from the coastal mountains which are Perhumid, most of the country is either Humid or Subhumid. The Perhumid zones are associated with the lower Mekong Delta and the higher land in the east and north, whereas the Subhumid zone covers much of the central plain.

3.3 Physiography and Geology

Physiographically Cambodia is divisible into:

- (i) The coastal mountains, the Cardamom Chain and the Elephant Chain
- (ii) The Tonlé Sap and Mekong plain
- (iii) The hill country along the Vietnam and Laos borders

The coastal mountains resemble the Cordilleras of Vietnam but are on a smaller scale. They are composed of sandstone plateaux and some crystalline massifs. In general they rise steeply from the sea and slope more gradually to the interior. This, coupled with the higher rainfall on the seaward slopes and hence increased erosion, has resulted in very broken topography, especially in the areas of crystalline rock. The topography is more even on the leeward slopes.

The Mekong plain is considered to be of structural origin, since it owes its lack of relief to the horizontal position of its underlying sedimentary beds. Most of the plain is composed of clay deposits but occasional sandstone beds give rise to small upland areas.

A characteristic feature in Cambodia is the Great Lake, or Tonlé Sap (actually the name of the channel linking the lake and the Mekong), which lies in the western part of the plain and occupies the remaining area of what was probably a gulf of the sea. Some species of marine life which have adapted themselves to fresh water are still found in the lake.

Land uplift caused obstructions in the bed of the Mekong and cut the lake off from the sea. With the present rate of deposition of alluvial material it is probable that the area of the present lake will be progressively restricted. The Tonlé Sap acts as a regulator of the Mekong floods. During June to October, when the water level in the river is high, the current runs into the lake from the river causing the Tonlé Sap to double its surface area. The flow then reverses as the river level drops. This periodic inundation creates conditions suitable for extensive rice cultivation.

Rivers which flow into the lake from the Cambodian uplands are also highly seasonal in flow. Low-lying land, all under 200 m in elevation, occupies by far the greater proportion of the total land area. It runs out against the Cardamom and Elephant Chain mountains in the west and southwest of the country, ascends a series of steps to the Annam mountains in the east and is bounded to the north by the Dang Raek range in Thailand and the southern extension of the mountains of Laos.

The narrow zone of hilly country along the border of South Vietnam in the east is in fact the western extension of the Annam Cordilleras descending gradually to the Mekong plain. Basalts of varying age predominate along the southern portion of the boundary, while granites, schists, gneiss and other igneous and metamorphic rocks are present as well further south.

3.4

Soils

The major soils of Cambodia have been surveyed and mapped by Crocker (1963) to a scale of 1 : 1,000,000.

Lacustrine and other alluvials (Types 13, 14, 15), hydromorphic soils (Types 5, 6, 7, 8), acid lithosols (Type 11), red-yellow podsols (Type 1) and plinthite podsols (Type 4) among others all cover relatively extensive areas of lowland plain. Acid lithosols, red-yellow podsols plus small areas of basic lithosol appear to be the main soils of the coastal mountains. Latosols and basic lithosols are associated with the hilly basaltic country in the east. Some red-yellow podsols are also shown and are presumably associated with acid rocks. The soil of the pine-bearing Kirirom Plateau is shown as a red-yellow podsol. This is assumed to be equivalent to Moormann's red-yellow podsolic. A soil description given by Setten (pers. comm.) of the pine areas on Kirirom Plateau is consistent with a podsolic soil.

A brief examination of one soil profile under lowland pines at Srakanome near Kompong Thom revealed a podsolic soil merging from a greyish sandy loam near the surface to a pallid clay sand at depth. Marked leaching was noted between 3" and 4" in the profile under a darker humic A1 horizon. Horizon development was poor, with little evidence of a textural B horizon. The AO horizon comprised $\frac{1}{2}$ " of dry leaf litter.

A comparison of other known occurrences of P. merkusii as shown on Map 39 in the Geographical Distribution of the Pines of the World (Critchfield and Little) and the general soil map of Cambodia shows that there is a strong likelihood that the distribution coincides with the occurrences of red-yellow podsols, although there are considerably greater areas of podsols than there are of pine forests.

3.5

Forest Types

Most of Cambodia, apart from the central plain and the flat plains of the Mekong which are seasonally inundated, is naturally a forested region. Forests constitute one of the principal natural resources of the country. Due to the great range in precipitation, and thus in the severity of periods of moisture deficit, the forest itself varies considerably in specific composition and in physiognomy. Open deciduous stands characterize the drier zones while the wetter perhumid zone supports dense tropical rainforest. There is of course a series of gradations between the extremes. Large areas of forest in the vicinity of the heavily populated central plain have been cut over many times in cycles of shifting cultivation and have in consequence been modified to secondary forest or reduced to a form of savanna.

Tan-Kim-Huon (1955) distinguishes six vegetation types in Cambodia and the information which follows is based on his paper. Forest occupies some ten million hectares in Cambodia. As a consequence of the ecological conditions and the degree of anthropic interference in particular localities five main forest types may be recognised. These are listed below together with the area occupied by each type:

1. Evergreen Forest (Forêt dense)	3,000,000 hectares
2. Open or Deciduous Forest (Forêt claire)	5,000,000 "
3. Freshwater Swamp Forest	800,000 "
4. Mangrove Forest	50,000 "
5. Rear Mangrove Forest	100,000 "

3.51 Evergreen Forest (Forêt dense)

This probably corresponds to the tropical evergreen category in Thailand. It is described as being rich in woody material but generally poor in exploitable stems except in inaccessible areas of the Cardamom Mountains and on the Gulf of Thailand. This type occupies extensive tracts where adequate precipitation and deep red soil favour its development. It produces the bulk of the country's large timber. The main timber species occurring in it belong to the two families Dipterocarpaceae and Leguminosae. Important Dipterocarp genera include Dipterocarpus, Anisoptera, Shorea and Hopea.

Tan-Kim-Huon (1955) considers this to be the true climatic climax type over much of Cambodia, having a potential extent of six to seven million hectares instead of the present three millions only.

3.52 Open or Deciduous Forest
(Forêt claire:cf. Deciduous forest of Thailand)

These are open forests or woodlands in which Dipterocarps again predominate. The ground cover is grass which is more or less sparse and subject to annual fires. The Dipterocarps are locally exploited to provide community requirements for wood. In some areas P.merkusii occurs in groves in this forest type and may be tapped for resin. The pure stands of P.merkusii on Kirirom Plateau come within this classification. Open or deciduous forest may be the climax type where the soil is thin and rocky or very poor, but may also result from the degradation of evergreen forest (forêt dense). In the latter case fire protection would result in a gradual reversion to evergreen forest.

3.53 Freshwater Swamp Forest

This type occurs in places along the edge of the Tonlé Sap and on parts of the flood plain of the Mekong. It is inundated by the flood waters during the period May to November but tends to dry out with the progress of the dry season.

3.54 Mangrove Forest

Rhizophoraceae occur in typical mangrove formations on the coasts of the Gulf of Thailand.

3.55 Rear Mangrove Forest

This type lies inland from the mangrove forest proper and is dominated by Melaleuca leucadendron (Myrtaceae).

3.6 P. merkusii in Cambodia

3.61 Distribution

P. merkusii is known from several localities in Cambodia and it seems possible that further small areas may be discovered. The stands on the sandstone plateau of Kirirom, which lies in the southwest of the country about 115 kilometres from Phnom Penh and just to the north of the road to Sihanoukville, are now relatively well-known and have been referred to by the following authors among others: Aubreville (1957), Bryde et al. (1965), Cooling (1967).

The species has also been recorded near Kompong Thom, north of the Tonlé Sap, in Bambe forest (Aubreville, 1957) and in the forests of Srakanome, Rovieng, O Po and O Mean in the same region by Bryde et al (1965) who also obtained information on the existence of at least two similar areas between Kompong Thom and Siem Reap.

Mirov (1967) reports P. merkusii in Cambodia not far from its occurrence near Srisaket in Southeastern Thailand along the 14th parallel, and further south in Pursat Province, to the south of the Tonlé Sap. The Cambodian Forest Service has collected seed from this pine in Komreng Forest Reserve, also near Pursat (Ou Thuok, pers. comm., 1967).

The total extent of pine forest in Cambodia has been estimated at 30,000 hectares by Bryde et al (1965). This comprises 11,000 ha. of mainly pure pines on Kirirom Plateau, some 10,000 ha. of fairly well-stocked but mixed pine and hardwoods in the Srakanome and Rovieng Reserves, 3000 ha. in Po Pok, and 6000 ha. between Kompong



Plate 5a. Mature *P. merkusii* forest, Kirirom Plateau, 700 m, Cambodia. Pure pine in foreground on podsollic soil, gallery forest of Lauraceae and Fagaceae along water-course in background: note sharp ecotone. Pine stand rather open but no large canopy gaps exist; only occasional seedlings can become established under these conditions. Tree next to figure is 95 cms d. b. h. and 33 m tall.

Photo: Feb. 1961.



Plate 5b. Heavily stocked stand of *P. merkusii* in late pole stage, Kirirom Plateau, Cambodia. Note excellent bole form and apparently even age within group

Photo: Feb. 1961

Thom and Siem Reap. The mixed hardwood/pine forest in Pursat Province has not been taken into account in these estimates which may also omit the groves noted by Mirov (1967) near the Thai border south of Srisaket.

3.62 Description of *P. merkusii* Forest

P. merkusii occurs in two different physiographic regions in Cambodia under conditions which are ecologically dissimilar: on a sandstone plateau some 600 m to 900 m in altitude, and at various points near the central plain surrounding the Tonlé Sap at elevations ranging from 10 to 300 m.

3.621 Kirirom Plateau (See Plate 5)

The plateau is roughly circular in outline and is traversed by three almost parallel rocky ridges orientated north to south. The surrounding scarp drains inwards towards a central valley which cuts through the rim in the southeast. The topography is thus somewhat hilly and irregular with an altitudinal range from about 500 to 980 m at Kam Chiveath, the highest point. The average altitude is 600 to 800 m above sea level (Setten, pers. comm., 1967). The parent material is sandstone (Aubreville, 1957) and the soils of the plateau region are shown as red-yellow podsols on the 1:1,000,000 soil map (Crocker, 1963). Much of the plateau is covered by pure *P. merkusii* forest often with a relatively open canopy but varying from stands of very open over-mature trees to dense pole crops and patches of more or less even-aged regeneration of varying extent. A constant feature of the pine areas is the presence of relatively dense but only moderately tall grass cover interspersed by occasional herbs and a discontinuous broad-leaved understorey which includes *D. obtusifolius*, *Tristania* and *Melastoma* spp. Occasional areas of relatively dense woody understorey comprising several species were also observed. The pine area is however not continuous, being dissected by fingers of broad-leaved gallery forest along streams and drainage lines. *Lauraceae* and *Fagaceae* predominate in the gallery forest and in small pockets of hardwood forest in favourable sites in valley heads. The scarp faces leading up to the plateau are clothed either by closed-canopy hardwood forest or an open forest dominated by *Dipterocarpus obtusifolius*.

The ecotone between pine and gallery forest is almost always sharp, only very occasionally is a large dominant pine seen in the margin of the gallery forest and in such situations there is no sign of pine regeneration (Cooling, 1967).

On some sites, thought to be at lower elevations, *Dipterocarpus*

obtusifolius was associated with the pine. The dominant impression is, however, that of a pure pine forest which in places resembles a plantation. Aubreville (1957) describes it as "A splendid pure forest of pine over a grassy layer".

3. 622

Srakanome, Kompong Thom

Only Srakanome of the various lowland sites was visited by me but this is believed to be reasonably representative of P. merkusii forest on the plains north of the Tonlé Sap in the region of Kompong Thom.

The forest is situated some 30 kilometres to the northwest of Kompong Thom. P. merkusii is here associated with two types of hardwood forest - semi-humid (moist deciduous) forest relatively rich in species, see Table 3 ; and a dry deciduous type in which D. obtusifolius predominates.

Table 3

Species commonly found in Moist Deciduous Forest (Semi-humid forest),
Srakanome, Cambodia

<u>Lagerstroemia</u> sp.	<u>Lythraceae</u>
<u>Sindora cochinchinensis</u> H.Bn.	<u>Leguminosae</u>
<u>Peltophorum ferrugineum</u> Benth.	"
<u>Shorea cochinchinensis</u> P.	<u>Dipterocarpaceae</u>
<u>Anisoptera cochinchinensis</u> P.	"
<u>Hopea odorata</u> Roxb.	"
<u>Irvingia harmandiana</u>	<u>Simarabuceae</u>

(Information provided by Cambodia Forest Service)

In the moist deciduous type pine is present in groves and small groups in clearings or glades and occasionally also on the forest edge against edaphic grassland or Melaleuca leucadendron/Baeckea associations on poorly drained depressions. Both pines and hardwoods attain large dimensions: pines of 45 cms diameter and 27 to 33 m tall are fairly common. However, a surprising number of large old pines were found to be dead or dying. As no obvious cause could be found the possibility of an edaphic factor, such as an exceptional fluctuation in the water table, was considered. The topography is flat and though the soil is very sandy it is relatively fine and compact. This, coupled with low elevation, about 13 m, and very seasonal but heavy rainfall, could conceivably result in temporary waterlogging in an exceptional year. The weakening of the trees by excessive resin tapping is another possibility.

Aubreville (1957) who earlier visited the same area commented on the successful invasion of tropical forest by P. merkusii and noted that the pine has succeeded in glades and in abandoned rubber (Hevea) plantations and other clearings. He states that the rubber failed due to poor soil conditions.

In the same region P. merkusii was encountered in mixture with Dipterocarpus obtusifolius and a few other hardwoods. In this case the pine tended to be scattered throughout the stand and not in gregarious groups as was the case in the moist deciduous forest. No significant change in soil could be detected between these two types of forest.

3.63 Growth Habits

The pine stands on Kirirom Plateau are very impressive: form is excellent and the trees are of very upright habit with no tendency to sinuosity. Aubreville (1957) considers that this population "certainly belongs to a very good race". On the basis of a visit to Kirirom in 1960 the author strongly recommended this provenance for trial in Zambia (Cooling, 1967). The stem form of the P. merkusii in the mixed pine/hardwood forests at Srakanome is also very satisfactory. Unfortunately, a number of the large dominants were dead or dying at the time of my visit in 1967 (cf 3.62).

3.631 Size under Typical Conditions

At Kirirom the FAO team collecting data during 1965-66 found the largest tree measured to be 123 cm d.b.h. and 35 m in total height. They reported that an average commercial bole height of 16 to 18 m is obtained at a d.b.h. of 55 cm and remains reasonably constant at that height for all greater diameters. Aubreville (1957) records the existence of individual old pines which exceeded 40 m in height and 80 cm in diameter. The largest tree measured by me in 1961 was 138 cm d.b.h. and 45.7 m in total height. However, although stem form is very impressive, the height attained by this provenance in the natural stands is not outstanding for the species.

In the pine groves at Srakanome typical dominants averaged about 70 cm d.b.h. and 33 m in height.

3.632 Crown Shape and Branching

At Kirirom the crowns are pyramidal to somewhat ovoid in youth, but the trees become more or less flat-topped at maturity. Branching in young trees is uninodal but becomes irregularly spaced

and fairly heavy in older trees. In denser groups particularly the tree cleans itself well.

In the mixed pine/hardwood forest, as at Srakanome, crowns generally appear more attenuated and lighter in youth than at Kirirom. This is likely to be due to competition by the encircling hardwoods owing to the relatively small size of the pine groves. The crowns of dominants are, however, quite heavy and spreading. A check on the relationship between growth rings and whorls on five random younger trees at Srakanome gave the following results:

Table 4

Relationship between numbers of branch whorls and growth rings at Srakanome

Tree No.	No. of Growth Rings at 30 cm above ground level	No. of Branch Whorls above 30 cms	D.B.H. in cms	Diam. at 30 cms above ground level	Total height in metres
1	23-27	24	23	25.4	16.8
2	18	21	13.5	15.6	12.2
3	19-20	19	14.5	16.0	11.9
4	23	17	21.5	23.5	15.8
5	24	24	19.0	20.3	15.8
Totals	109	105			72.5
Arith. Mean	22	21			14.5

The uninodal habit is clearly demonstrated and in these five trees the average whorl length (height increment) is 70 cms.

A similar check at Kirirom confirmed a uninodal habit in pole sized trees there too.

3.633

Bark

The bark of *P. merkusii* in Cambodia is dark grey-brown in colour, vertically ridged and less distinctly fissured horizontally. It is inclined to be superficially scaly and is typically thick, usually to the order of 6 cms on mature trees at breast height. However, working in the forest at Kirirom, Setten (pers. comm., 1967) distinguishes two forms of bark. Some trees have thick, deeply fissured bark while others have smooth comparatively thin bark.

3.634

Root System

Only very occasional wind thrown trees are seen and the indications from road cuttings are that this species is usually securely anchored by spreading lateral and deep tap roots.

3.635

Cones and Male Flowers

Cones on both the Kirirom and Srakanome populations are borne in ones, twos and occasionally threes and project roughly at right angles to the branch of attachment. Female cones are usually borne high in the crown towards the ends of well exposed laterals: they are thus conspicuous. The majority of cones probably ripen during March - May in both localities but there is evidence of a good deal of tree to tree variation. In the crowns of older trees male flowers are borne in clusters on branchlets in proximity to the female cones. In younger trees there is a tendency for much of the pollen to be borne on the lower branches. The average size of fully developed cones is about 7.9 cms long by 6-7 cms wide.

3.636

Seed

Seed from Kirirom is relatively large and averages 31 grams per 1000 or 32,000 per kilo, whereas seed from the lowland provenance collected in Komreng Forest Reserve, Pursat averages only 24 grams per 1000 or 41,500 per kilo. The Komreng seed is thus similar in weight to that from the lowland provenance at Srisaket, Thailand.

Sufficient seed is not available from Srakanome to permit a really valid comparison but the indications are that it is similar in weight to the seed from Pursat. Average dimensions of clean seeds are as follows:

Kirirom	8 mm long by 5 mm wide
Pursat	7 mm long by 4 mm wide
Srakanome	7 mm long by 4 mm wide

The unequal sided wings, with seed attached, average about 26 mm by 7 mm at Kirirom and 30 mm by 7 mm at Srakanome.

The germination capacity of seed from various sources in Cambodia appears to drop rapidly with passage of time. Seed physiology and practical storage conditions both require careful investigation as suggested in connection with the seed of this species in Thailand.

3. 64 Regeneration

3. 641 Natural Regeneration

1. Kirirom Plateau

P. merkusii on Kirirom behaves rather like P. kesiya and exhibits the characteristics of a "light demander". All regeneration of any consequence was in canopy gaps of varying size. Regeneration was most vigorous and most profuse in the larger gaps and decreased towards the gap perimeters. Though widely scattered seedlings were present among the ground cover under mature stands, they plainly made no headway until released by the death or removal of sufficient trees in the canopy. At the time of my previous visit, in 1961, the forest had not been subjected to exploitation owing to its previous inaccessibility.

A distinctive feature was the succession of more or less even-aged groups, representing most age classes, and varying in extent from about 0.05 to 1 or more hectares in area. There are several possible explanations for these groups. They may betray former anthropic interference, possibly cultivation, but more probably fires set for hunting. Or, as previously noted (Cooling, 1967), groups of over-mature trees having lost their vigour become prey to various forms of damage which permit fire to gain a hold on the trunk itself; once that happens the destruction of all trees in the group might be accomplished in a relatively short time, thus permitting even-aged regeneration in a fire hole. Again, as postulated in the case of the pure pine on Phu Kradoeng Plateau in Thailand, the grouping may be the result of relatively small islands of seedlings having escaped fire damage in a particular year or series of years when canopy and other conditions favoured establishment. A combination of some or all of these factors may of course be involved.

During the course of my visit in 1961, and again in 1967, consideration was given to the ecological status of the pine in relation to the hardwoods of the moist-type gallery forest and the dry deciduous forest on parts of the scarp. Observations in pine regeneration show that it is really vigorous only under open conditions and in the absence of excessive

competition from grass or hardwoods. The most dense and vigorous regeneration seen was in fact on an area from which ground flora and top soil had been removed by a bulldozer. Good regeneration was observed in patches of burnt grass under an open pine canopy, but given a suitably large opening in the pine canopy, a reasonable stocking of regeneration is possible even in grass of moderate density.

Pine regeneration was totally lacking under the canopy of gallery forest. On certain favourable sites, where species of the gallery forest were gradually encroaching on previous pine areas as a consequence of fire protection, the pine regeneration, even up to the small pole category, had become very attenuated and thin-crowned and would obviously succumb when finally overtopped by the hardwoods. The converse of this situation was seen where fire had eroded the gallery forest margin: in such places, provided the ground flora was not too lush, pine regeneration quickly became established.

Where dry deciduous forest and pure pine met the ecotone was less distinct than in the case of pine and gallery forest, and the seedlings of both (mainly D. obtusifolius and P. merkusii) could be found in various stages of growth within a restricted area.

Despite growing in quite dense ground cover in some cases, the seedlings were found to have a definite grass stage lasting an estimated 3 to 5 years. Owing to the attenuating effect of shade the grass stage was not very evident in some seedlings on the margin of the moist forest.

2. Srakanome Forest

In these low elevation forests pine regeneration was seen only in the larger clearings and glades in the moist type deciduous forest, or under smaller openings in the canopy of pine groups. There is thus a strong tendency for even-aged groups of varying size which almost always have a relatively clean but needle-strewn floor. No regeneration could be found at all under the normal hardwood canopy despite careful search. Pine saplings on the edge of a group were attenuated and much lacking in vigour if overtopped by surrounding hardwoods.

In the areas of dry type deciduous forest with mixed pine and D. obtusifolius, regeneration tended to be dispersed throughout the forest and not confined to small groups. Even so, the most vigorous regeneration was to be found on needle-covered patches where the grass was suppressed. The thickened stem of the grass stage seedling was much more pronounced in these open conditions.

3. 642

Artificial Regeneration

No artificial regeneration of P. merkusii was seen in Cambodia but the possibility of supplementary planting in conjunction with exploitation is of interest to the Department and was discussed.

It is possible that provision for planting of some areas of P. merkusii and the trial of other exotics may be included in the prescriptions of a working plan for the Kirirom pine forests.

3. 65

Silvicultural Treatment

Intensive silvicultural treatment has not yet commenced in the pine forests. The first pine area likely to come under the prescriptions of a working plan is Kirirom where an FAO team in conjunction with the Forest Service has collected the necessary basic data.

Some forest areas near Kompong Thom are being worked on a girth limit and small-scale operations are also now under way at Kirirom, again to a defined girth limit.

Fire protection has been applied to certain of the pine areas including Kirirom in recent years, but it is too early to assess the effect. It is believed that provision will be made in the working plan to test the controlled use of fire in regenerating the felled coupes.

Certainly the existence of relatively large and accessible areas of both lowland mixed pine/hardwood and higher elevation pure pine stands affords Cambodia an excellent opportunity to further knowledge of the ecology and silviculture of a potentially valuable species. It is to be hoped that circumstances will permit this opportunity to be exploited fully as the knowledge gained will be of benefit not only to Cambodia but to other countries as well.

3. 66

Rate of Growth

3. 661

Kirirom

Aubreville (1957) stated that many trees in the forest showed very little annual increment and were up to 250 years old.

An FAO team recently carried out an enumeration of the growing stock and I am indebted to Mr. G. G. K. Setten and to FAO for the information that follows:

Two inventories of the forest have been made. The first was

carried out by a French forester, M. Robbe, between 1948 and 1950, and comprised a 100 percent enumeration of all pine trees with a d.b.h. of 30 cms or more.

The second inventory, carried out by an FAO team in 1965, had two aims. Firstly to produce a photo-interpreted stock map on a larger scale than previously available, secondly to check whether the standing volume of the forest had changed substantially since the first enumeration and, if so, by how much.

The results of the check inventory showed good agreement with those of Robbe's 1950 enumeration and indicated an average standing volume under bark of 136 cubic metres per hectare $\pm$ 26 cubic metres (or 19.2 percent). Although expressed as an overbark volume, the 1950 figure of 132 cubic metres per hectare falls within this range. Discrepancies were found in the volume of growing stock in the various size classes recorded by the two inventories. This is partly explained by differences in the limits of the size classes used, and partly by the fact that the fire control instituted between the two inventories has permitted more of the trees in the smallest size classes to survive than was previously the case.

P. merkusii at Kirirom displays rings in cross section which the FAO personnel suspected to be annual rings caused by the annual alternation of wet and dry seasons. In 1965 cross sections were sent to the Forest Products Research Laboratory, C.F.R.I.O., Melbourne, Australia. The Laboratory confirmed the view that the growth rings were in fact annual and gave ring counts of the sections which had been sent to them. The results were as follows:

Disc.No.	<u>Table 5</u>	
	Diameter (cms)	Ring Count (complete rings)
1	10.2	44
2	21.2	47
3	33.3	74
4	45.5	159
5	57.0	132
6	71.5	156

In the same year the FAO team, using Pressler borers, made ring counts covering the past fifteen years on 1000 trees having a diameter range from the 10 cms d. b. h. class (overbark) to the 115 cms d. b. h. class (overbark). They show that the average annual diameter increment per diameter class during the past fifteen years was approximately as follows:

Table 6

D. B. H. Class (cms)	Mean annual d. b. h. increment in cms
10 - 20	0.51
30 - 40	0.34
50 - 60	0.29
70 - 80	0.27
Over 80	0.26

The next step was the correlation of the diameter class figures with age on the assumption that the diameter growth over the past fifteen years was representative thus:

Table 7

D. B. H. Class in cms	Mean annual d. b. h. class increment in cms	Years taken to reach next d. b. h. class	Age in years
10			(say) 10
	0.51	20	
20			30
	0.42	24	
30			54
	0.34	29	
40			83
	0.30	33	
50			116
	0.29	35	
60			151

Setten points out that the arithmetical mean of the three largest cross sections sent to Australia is as follows:

	<u>D. B. H. (cms)</u>	<u>Age in Years</u>
	45.5	159
	57.0	132
	71.5	156
Totals	174.0	447
Arithmetic mean	58.0	149

To supplement the foregoing data 55 trees of all size classes were taken at random in the forest for complete ring counts. The following mathematical relationship was established:

$$Y = 7.809 + 0.2235X + 0.00037X^2$$

where Y = d. b. h. (o. b.) in cms and

X = age in years

This sample gives the following results which demonstrate even slower growth than that shown in Table 7 above:

Table 8

Diameter Class in cms	Age in Years
10	10
20	50
30	87
40	121
50	152
60	180

Setten considers that this random sample may have contained an excessive number of suppressed trees. If the ten largest only are taken the growth curve resembles closely that obtained from Table 7 above. Even so, it is clear that in its present management state the P. merkusii forest of Kirirom represents a very slow-growing species of tropical pine.

In order to assess what the diameter/age relationship would be if the forest were brought under management and the trees were maintained in a dominant condition throughout their lives Setten selected twenty of the largest trees on the assumption that these had probably been dominants for the greater part of their growth. To these were added the five largest trees of the random 55 previously examined.

For each tree the diameter was measured at every tenth complete ring, i. e. at 10, 20, 30, 40 years etc. A diameter age curve was produced and the mean diameter of all 25 trees at each ten year period was also plotted to provide a single curve for the combined data. This gave the following figures:

Table 9

Age in years:	10	20	30	40	50	60	70	80
Mean basal diam. in cms:	8	16	24	31	37	43	47	51
Age in years:	90	100	110	120	130	140	150	
Mean basal diam. in cms:	55	58	61	64	67	69	91	

The growth rates displayed by the dominants are considerably faster than those in Tables 7 and 8 but it is not unreasonable to assume that a growth rate of this order could be attained if the forest were brought under proper management and adequately thinned.

No data are available on the increment of total height. However, from the Pressler borings and related studies, and a knowledge of the development of commercial height, Setten has prepared the following table:

Table 10

D. B. H. Class (cms)	Age in years	Average commercial ht. in metres	Average total ht. in metres
10	10	4	6
20	30	7	14
30	54	12	19
40	83	14	22
50	116	15	24
60 and over	151	16-18	25-30

The FAO survey indicates an actual volume increment between the two surveys of approximately 1.5 cubic metres per hectare per annum over the whole forest, and Setten considers that a net mean annual increment of at least 5 cubic metres per hectare per annum should be obtained at 70 to 80 years of age.

3.662

Srakanome

No published growth rate data are available for the lowland pine forests and these forests were not included in the FAO working plan survey. A very approximate idea of growth rate may be obtained from the increment borings made by me in 'representative' dominants in the 20-30 year age (growth ring) class.

Table 11

Tree No.	Growth Rings	Radius from pith to bark in mms	Mean annual diameter increment in mms
1	22	8.3	.76
2	20	5.9	.59
3	26	5.8	.44
4	25	9.3	.75
5	30 *	7.8	.53
Totals	123		3.07
Arithmetic mean	25		.61

* Rings difficult to read. Several false rings assumed.

From this crude check the arithmetic mean tree of the five sampled is 25 years old and has a mean annual diameter increment of 0.61 cms. The corresponding height increment is estimated at 0.7 metres. These growth rates are intermediate between the 'whole forest' and the 'dominants only' data for Kirirom.

3.67 Injuries and Protection

3.671 Fire

The adaptation of P. merkusii to the hazard of fire has been discussed in section 2.661 dealing with the Thai provenances. It applies equally in Cambodia. However, the denser grass cover throughout the pine area on Kirirom Plateau appears to result in more certain destruction of seedlings than is the case in areas where the cover is relatively sparse, as in some forests in Thailand and in the glades at Srakanome. In this respect Kirirom and Phu Kradoeng Plateaux are very similar.

Damage to standing trees is relatively slight in the areas visited although charring at the base of many trees in Kirirom was witness to the prevalence of fire there before the present protection measures were applied some years ago. Annual fire through the grass layer at Kirirom is mentioned by Aubreville (1957) who says that patches of young plants observed from place to place clearly correspond to groups spared by chance from the fire.

The role of fire in the regeneration of these forests should definitely receive further study, preferably in properly sited plots in which contrasting regimes may be compared.

On average it is probable that mortality is very nearly complete for seedlings less than three years old when fires sweep through moderately dense grassy ground cover. Plants from 3 to 5 years old are quite resistant and from five years onwards may be expected to survive most fires.

Protective early burning or patch burning might prove a satisfactory means of assisting pine regeneration.

Concerning the origin of fire in natural forest shifting cultivators, when present, must be the prime suspects since the clearing of garden sites depends so much on the use of fire. Hunters are another frequent cause of fire which is deliberately set to flush the game from cover or to attract animals to restricted areas of fresh green shoots. Setten (pers. comm., 1967) quotes Ashton to the effect that lightning may play an important role on an exposed plateau such as this.

3.672

Shifting Cultivation

Shifting cultivation cannot be demonstrated on present knowledge to have influenced pine stands on Kirirom. However, there is at least one patch of grassland on the plateau which, in my opinion, is of anthropic origin. This view is understood to have been earlier expressed by others. The grassland in question is surrounded and is being encroached upon by pines; it has the characteristics of a man-made clearing and there is no obvious edaphic explanation for the lack of trees.

The position in the lowland forest near Kompong Thom is different. This region is said to have been subjected to shifting cultivation over a long period of time and it seems very probable that the pine glades within the moist deciduous forest mark improverished garden sites on a soil type which, to begin with, had little resilience. Attention has been drawn to Aubreville's report of the colonisation of abandoned rubber plantations by pine (Cf. 3. 62).

Thus, to a point, shifting cultivation encourages the spread of pine at the expense of hardwoods. But, as in other parts of Southeast Asia, the pine itself becomes vulnerable once land-hunger compels reduction in the cycle of cultivation and increased density of population, plus the absence of effective control, permits annual firing over an extensive front.

3. 673

Wind

Wind does not appear to be an important factor in the ecology of P. merkusii in Cambodia and the species may be regarded as wind firm in its natural habitat.

3. 674

Insect Pests

Some evidence of cone-boring insects was observed but no damage by shoot borers was noticed. Weak, over-mature trees are subject to attack by many borers, as is the case with fallen timber, but insects do not appear to pose a serious threat to the natural standing crop.

3. 675

Fungi

Fungi do not appear to cause serious damage in the pine forests.

3. 68

Wood Properties and Uses

Little published information is available on P. merkusii timber from Cambodia. In an anonymous paper on the pines of Indo China in Bois et Forêts des Tropiques (No. 35, 1954) it is stated that small quantities of timber from Kompong Thom were exported to France between 1918 and 1930 where they were sold as pitch pine of Cambodia. The strong resin content and really remarkable quality of the timber made possible its substitution for pitch pine from America. However, transport difficulties and production costs inhibited the trade.

Expressed on the basis of oven-dry weight and saturated volume, density determinations on the increment cores collected by me give values of about 0.42 for the inner ten rings and about 0.53 for the outer ten rings of trees in the age class 20 to 30 years. Density determinations on wood from a felled tree at Kirirom gave an average value of 0.52 on the basis of saturated volume and oven-dry weight. On an oven-dry volume and weight the specific gravity was 0.59.

Average fibre length, on the basis of 50 fibres counted from the same piece of Kirirom pine, was found to be 6.54 mm. This may

not be representative of the stand nor indeed of the tree concerned.

3.69 Oleoresin

The good yield of resin obtainable from P.merkusii is known throughout Southeast Asia, and Cambodia is no exception. Current tapping by villagers was encountered in the Kompong Thom area though it does not appear to be well organised nor controlled. The potential value of the Kirirom forests as a source of resin aroused the interest of the Forest Service and led to a start being made on an access road during the early 1940s. Tapping trials initiated at that time were not followed up and many of the trees which had been tapped died. (Aubreville, 1957).

3.70 Seed Availability

Both the Kirirom and Srakanome forests are readily accessible by road and with the commencement of exploitation should present good opportunities for the collection of seed. At Kirirom in particular it would be advisable for outstanding phenotypes to be selected and marked so that they may be left as seed bearers when felling reaches the coupes in which they are located. In view of the slow growth but generally excellent form of the Kirirom trees selection for vigour on the basis of increment core sampling might be rewarding.

Although it is likely that the seed requirements of the Cambodian service itself will expand, a small seed-collecting team properly equipped and available for a sufficient length of time should be able to secure substantial quantities of seed. The prior requisite as emphasised earlier is a study of seed physiology and of storage conditions so that field effort is not wasted through subsequent loss of seed viability in storage. No specially designed cold storage facilities for seed are at present available in Cambodia.

4.0

VIETNAM

4.1

General

South Vietnam comprises Cochin China and Annam (to the 17th parallel), both former provinces of French Indo-China and totalling some 170,000 kilometres in area. The alluvial lowlands of the Mekong Delta in the south represent the 'rice bowl' of a vast area. There is a very high concentration of population in the rice producing region of the Delta and on the relatively narrow coastal plain. However, South Vietnam is remarkable for striking regional variation in population density. Among several reasons for this Nuttonson (1963) suggests that the fear of malaria in the upland areas may be important. He notes that Anopheles minimus, one of the most dangerous Anopheles species, thrives in the clear mountain streams, whereas the stagnant waters of the thickly populated deltas are less favourable to these mosquitos. The result is that people of the lowland areas fear not only to move to the highlands but even to take a trip there. Another powerful factor is the veneration of ancestors and hence the desire to remain in the locality of origin. These considerations are rather outside the scope of this paper except that the incidence of malaria in the highlands calls for appropriate precautions during seed collecting visits.

4.2

Climate

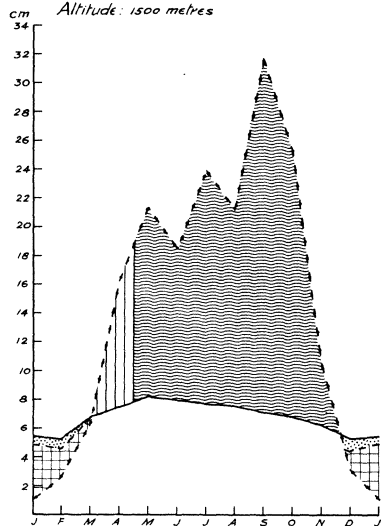
The climate of South Vietnam is essentially tropical although the altitude of the Annamese Mountains results in sub-tropical conditions in parts of the highlands.

There are three main seasons: hot, March to May; wet, end of May to October; and cool, November to February. The rains are brought in by the southwest monsoon, while the dry season coincides with the northeast monsoon. The wettest parts of the country are the highlands of the Annam Range, the southern slopes of which receive high rainfall due to their orientation and relative proximity to the coast. In the vicinity of Pleiku (781 metres), for example, rainfall exceeds 2500 mm. At Dalat (1500 metres), in the centre of the southern highlands, annual precipitation averages 1815 mm while the higher mountains northeast of Dalat, the massifs of Nam Nung and Bidoup, are said to receive 3500 mm. Further to the south on the frontal slopes of the same range Djering (972 m) receives 2059 mm, while Blao (850 metres) receives some 2881 mm.

FIG.3. WATER BALANCE DIAGRAMS: VIETNAM

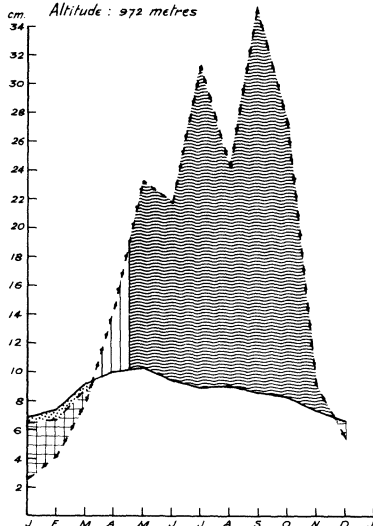
DALAT, VIETNAM

Location: $11^{\circ}57'N$ $108^{\circ}26'E$
Altitude: 1500 metres



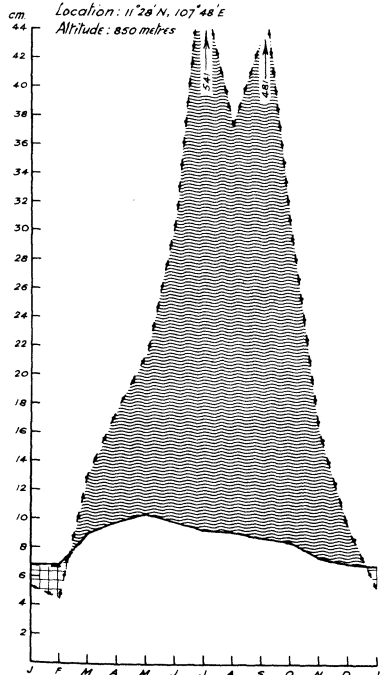
DUIRING, VIETNAM

Location: $11^{\circ}54'N$, $108^{\circ}05'E$
Altitude: 972 metres



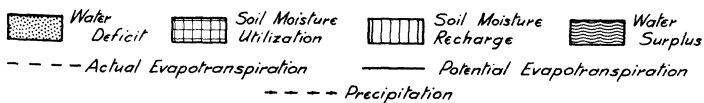
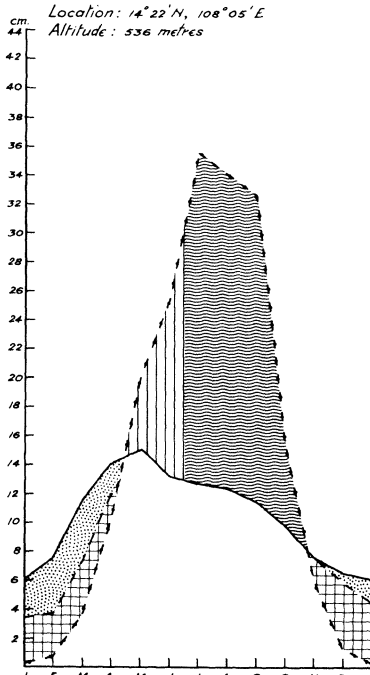
BLAO, VIETNAM

Location: $11^{\circ}28'N$, $107^{\circ}48'E$
Altitude: 850 metres



KON TUM, VIETNAM

Location: $14^{\circ}22'N$, $108^{\circ}05'E$
Altitude: 536 metres



Precipitation along the coast varies according to the direction of the coastline. Rainfall is low where both summer and winter monsoons parallel the coast and may drop below 1000 mm. At Saigon (8 metres) precipitation averages 1985 mm per annum with a tendency for two maxima separated by a short dry period during the course of the wet season.

Along the east and northeast coasts the climate is marked by the dominance of autumn rainfall maxima. This is related to the typhoon period of October-November and not to the winter monsoon as such, although the monsoon air mass has traversed a considerable extent of ocean before reaching the cooler (winter) land mass of Annam.

It is important to note that the annual amounts of precipitation and also the time of onset of the rains show considerable variation for any one station.

Relief exerts a strong influence on temperature in Vietnam. At Dalat (1500 metres) the monthly minima of just below 0°C occur during January and February and white frosts are not uncommon in the dry season.

The extensive lowland areas in the south of the country are more uniformly hot and experience relatively little annual fluctuation in temperature. Summer temperature averages 29.4°C while winter temperatures average 26.7°C . In Vietnam, far more than in Thailand or Cambodia, humidity appears to be both variable and important. This is well emphasised by Nguyen Kha (1965) from whose paper the following extract is quoted:

"The annual variation in relative humidity is a function of temperature and rainfall. It varies inversely with the temperature and directly with rainfall.

Note here the over-riding influence of the monsoon which varies with aspect and topography.

The slopes exposed to the NE monsoon are always very humid. Condensation in the morning is very high. The Bidoup massif is continually hidden in mist even in the dry season. On the contrary the plateaux encircled by these heights have a low humidity throughout the year.

Topography also exerts a considerable influence."

As regards wind, the monsoon regime predominates and results in regular seasonal winds; in summer from the ocean to the land and in winter from the land mass to the ocean. However, the effect of topography does influence the wind direction quite considerably. In addition, South Vietnam is in the path of typhoons from the South China Sea. The period of maximum risk is October and November. High, violent winds and torrential rain characterise typhoons so there is considerable potential for serious damage to tree crops.

The influence of autumn precipitation is also apparent in the graphs for stations further inland and is presumably due to the same cause. (See water balance diagrams, Fig. 3.)

Reference to Map 1 shows that the low-lying plains and the mountain peaks tend to be in the Humid category, while middle elevations and some plateaux, depending upon aspect, are Subhumid.

4.3

Physiography and Geology

From a physiographic standpoint South Vietnam is divisible into:

- (i) The lowlands of the Mekong Delta
 - (ii) The uplands of the Annam Cordillera
 - (iii) The narrow alluvial coastal strip
- (i) The Mekong Delta comprises a vast and monotonously flat plain of alluvial deposits brought down from the hinterland. The Mekong River is some 4000 kilometres in length and is one of the great rivers of Asia. There is considerable evidence that it once drained into the sea into the vicinity of Phnom Penh in Cambodia. The seaward encroachment still continues at the rate of 60 metres per year (Dobbie, 1966).
- (ii) The eastwards limits of the Annam Cordillera are well defined since the mountains and plateaux rise steeply from the narrow coastal plains. Due to the steepness of the escarpments and the generally good rainfall the frontal slopes are strongly dissected. The western boundary is less distinct, sloping more gradually towards the Cambodian lowlands and resulting in gentler slopes and rounded peaks. From the level of Kontum northwards the boundary with Laos follows the crest of the mountain chain so that the drop towards the Mekong occurs in that country. The southern part of the Cordilleras in particular is characterised by resistant crystalline rocks, which form the

higher massifs. These ancient crystalline masses are partly covered by lava flows and are flanked to the west by old tubular sandstones. The basaltic lava flows have given rise to the laterised 'terres rouges' (now classified as dark red and reddish brown latosols by Moormann. See Section 4.4., Soils.)

North of the Song (river) Buong the chain-like character of the Cordilleras is more pronounced due to the fold/fracture structure involving extensive sandstone and limestone beds.

(iii) The coastal strip is in effect a series of small plains of various sizes tending to be cut off from the hinterland by the steep scarp faces of the Annam mountains. These plains are exposed to typhoons from the South China Sea and also to flooding by the torrential streams and rivers which flow down from the mountains of the hinterland. The larger plains and deltas are separated by cliffs and sparsely peopled uplands. The coastal strip supports over 200 people per square kilometre for the greater part of its length whereas the uplands average less than 20.

From the point of view of the natural occurrence of Pinus species one region of the Cordilleras is of particular importance. It lies in Central Vietnam and comprises the plateaux of Langbian and Haut Donnai.

The Langbian plateau consists mainly of crystalline rocks. Hercynian granites form the three massifs; Krong Pha in the southeast, the central area around Dalat, and the large massif extending northwards from Fyan to Chu Yang Sinh. Emerging Permian dacites form a series of peaks on these high plateaux. The plateau of Haut Donnai is covered by basaltic lavas dating from the end of the Tertiary but sandy schists metamorphosed by contact with Hercynian granites form the substratum of a good part of the plateau. A more detailed account of the geology and stratigraphy of the pine forest region is given by Nguyen Kha (1965).

4.4

Soils

The major soils of Vietnam have been described and mapped by Moormann (1961). In general the uplands are chiefly covered by the following major soil types:

- Type 18. Complex of mountain soils, mostly red and yellow podsolics and lithosolics.
- Type 19. Reddish brown latosols on basalt, plane to rolling topography.
- Type 20. Red and yellow latosols on basalt, undulating to rolling topography.

- Type 21. Earthy red latosols on basalt, undulating to rolling topography.
- Type 23. Reddish brown and red latosols, rolling topography.
- Type 11. Sandy podsollic soils on acid rocks, plane to rolling topography.
- Type 12. Red and yellow podsollic soils on acid rocks, plane to rolling topography.

In addition, various classes of podsollic and low humic glei soils are found on old alluvial sediments in the wider valleys.

The lowlands associated with the Mekong Delta comprise mainly grey podsolics on better drained areas (Type 14), and acid to very acid alluvials (Types 3 and 4), undifferentiated alluvials (Type 1) and saline alluvials (Type 2) along the coast.

So far as natural pine forest is concerned the important soils are the red-yellow podsolics on acid rocks (Types 12 and 18), the reddish-brown latosols on basalt (Type 19) and the earthy red latosols also on basalt (Type 21).

In Vietnam P. kesiya occurs predominantly on the podsolics whereas P. merkusii is typically found on the latosols. In this connection it is relevant to note that the latosols under consideration, although formed on basalt, are often deeply leached, acid and low in fertility. The following brief descriptions of each of the main soil types are based on those of Moormann (1961) and Dudal and Moormann (1964).

Reddish-brown latosols are described as developing exclusively on the weathering products of basalt. The profiles are uniform reddish brown clay, usually continuing to some depth under a more or less humiferous surface layer. These soils are not very fertile but have good physical properties as a rule. There is evidence that soils of this group in the pH range 4.5 to 5.0 are poor whereas those with a pH in excess of 5.0 are distinctly richer. Primary forest is seldom found on these soils: the natural vegetation is usually secondary forest or savanna with Imperata cylindrica.

The earthy red latosols occupy the major part of the large basalt plateau of the Pleiku/Kontum region with heavy rainfall (2000 to 3000 mm) but a marked dry season. Base saturation is low and the soils are thus rather poor and acid with an average pH of 4.5. Moormann (1961) considers that a good part of the fine fraction of the soil is composed of finely divided iron oxide and that certain characteristics such as dustiness when dry and lack of consistence of the beds are thus explained.

Other characteristics are low base exchange capacity and low water holding capacity, the latter coupled with a severe dry season rendering the soil liable to dry out completely.

The red and yellow podsollic soils represent the most widespread great soil group of Vietnam, occurring under all but the driest conditions in the country. They are to be found on a wide range of parent materials, including the weathering products of more or less acid rocks and old coarse or medium textured alluvial sediments. However, they are rarely found on basic parent materials like the weathering products of basalt. Morphology is to a large extent dependent on the nature of the parent material. In the vicinity of Dalat the modal profile can be observed and this shows a clear and characteristic horizon sequence. There is a humiferous grey-brown surface horizon, below which a yellowish-brown leached horizon occurs. Both are loamy and overlie a clayey red-yellow horizon of blocky structure which in turn grades to weathering or weathered rock. Many variations of this modal profile exist. Differences in texture between surface and deeper horizons are less pronounced on the more sandy parent materials. The depth of the profiles may vary from a few decimetres to more than two metres, depending on the slope and nature of the parent material. On slopes, the second leached horizon may be masked by the humic surface horizon. Lateritic concretions are often found in these profiles, usually occurring below the horizon of clay accumulation. Certain of the red and yellow podsollic soils are stony.

Red and yellow podsollic soils are relatively infertile. Their pH is approximately 4.5 and they have low base saturation. These soils have a low water-holding capacity and can become very dry in the dry season. The majority of these soils in Vietnam are under forest, both hardwood and pine, or savanna. Their main agricultural use is for shifting rice cultivation.

4.5

Forest Types

Five main types of forest are distinguishable in South Vietnam - mangrove, rear mangrove, open canopy forest or woodland, rain forest and the coniferous forests of higher altitudes (Dal, 1955).

4.51

Mangrove Forest

Coastal mangrove of Rhizophoraceae; particularly abundant at Camau Point in the extreme south of the country.

4.52

Rear Mangrove Forest

Consisting largely of Melaleuca leucadendron and situated on

the landward side of the true mangrove forest.

4. 53 Open Forest or Woodland (Forêt claire)

These forests vary considerably in appearance due to differences in edaphic and climatic factors. In total they cover some three million hectares in South Vietnam. These formations are adapted to survive the frequent passage of fire. They contain several useful species having timber with good mechanical properties and durability. Important species in the open forests include Shorea obtusa, Dipterocarpus intricatus, Pentacme siamensis, Dipterocarpus tuberculatus and Terminalia tomentosa. Other lesser known species are as yet only lightly exploited. Unfortunately, in the open forests, small size and crooked boles often limit utilization.

4. 54 Rain Forest (Forêt dense)

Much of the open forest formation has probably been derived from evergreen rain forest as a consequence of the long established practice of shifting cultivation and associated clearing by fire, 'rays'. High forest may thus be considered the climatic climax over much of Vietnam. The forest itself varies in structure and physiognomy according to precipitation, altitude and edaphic factors of the particular locality. Characteristic of such forest is the diversity of species. In consequence the forest produce is itself varied. Virtually all the large-dimensioned structural timber is obtained from this type of forest. The untouched primary forest, now extremely rare, is characterised by large buttressed trees with heavy seed. The canopy is dense and unbroken save for gaps caused by the death of an occasional old tree. Such gaps are quickly invaded and closed. Typical species in the rain forest of Central Vietnam are given by Nguyen Kha (1965) as Talauma gioi, Melanorrhoea laccifera, Aglaia gigantea, Tetrameles nudiflora, Lagerstroemia sp. and, occasionally in scattered pockets, Hopea dealbata, Hopea odorata and Pahudia cochinchinensis. At higher altitudes secondary forest resulting from the destruction of rain forest includes Quercus, Podocarpus, Pometia pinnata, Calophyllum etc. rather than the Dipterocarpaceae and Leguminosae of the lower elevations.

4. 55 Coniferous Forests

These may be almost pure, or mixed with hardwoods to varying extent. The coniferous forests on the southern plateaux are of the greatest economic importance and are estimated to cover a total of some 135,000 hectares, of which P. merkusii accounts for 45,000 hectares and P. kesiya 90,000 hectares. Some 70,000 hectares of the P. kesiya forest is in the vicinity of Dalat. The other conifers found in South Vietnam,

e. g. P. dalatensis, Keteleeriadavidiana and P. krempfii occur scattered among hardwood forest in which Quercus, Pasania and Castanopsis predominate. Podocarpus and Dacrydium are also encountered at higher elevations.

4. 6 P. merkusii in Vietnam

4. 61 Distribution

Nguyen Kha (1965) describes the Haut-Donnai plateau as the centre of distribution of P. merkusii in Central Vietnam. P. merkusii is not found in large continuous blocks nor in pure homogeneous stands as is the case with P. kesiya on the Langbian plateau. This fact complicates the problem of its delineation. Nguyen Kha distinguishes two main zones:

(1) The southern massif of Langbian which forms a transition zone between P. kesiya and P. merkusii. Here the two species grow together or in mixture with hardwoods, among which Dipterocarps predominate. The following forests are in this category:

- | | | |
|-------|-------------------|---------------|
| (i) | Pongour | 1100 hectares |
| (ii) | Prey | 4930 hectares |
| (iii) | Dangia | 2100 hectares |
| (iv) | Lang Hanh Finnorn | |

(2) Lower elevation forests, mainly P. merkusii with or without hardwoods. As one descends the mountains P. kesiya dies out and the stocking of P. merkusii increases from northeast to southwest from Finnorn to Djering and up to Dargna Massif itself where P. merkusii grows almost exclusively.

- | | | |
|-------|---|------------------|
| (i) | Dargna. Nearly pure <u>P. merkusii</u> . | 17, 500 hectares |
| (ii) | On the Cana Massif near Phan Rang at 800 m on the crests of the foothills | 2, 000 hectares |
| (iii) | As small islands amidst hardwoods, chiefly Fagaceae, on the mountains of Hala, Nui Thanh and Nui Chua. | |
| (iv) | On the Komtum-Anklé road, in small patches which have been severely degraded by fire and uncontrolled exploitation. | |

4. 62

Description of *P. merkusii* forests

4. 621

General Appearance (See Plate 6)

The *P. merkusii* forests are broadly divisible into a pure type with sparse shrub layer and a mixed type with dense or very dense shrub layer (Nguyen Kha, 1965). Pure stands, apart from several thousand hectares northeast of Blao are said to be rare. Nguyen Kha considers that natural evolution of pure stands is towards mixed stands unless some factor prevents it. Mixed stands vary from an open canopy hardwood formation with scattered pine of poor form over a sparse shrub layer, to relatively dense stands of *P. merkusii* and *D. obtusifolius* 'in perfect equilibrium' over an abundant shrub layer and a well-developed herb mat (Nguyen Kha, 1965). Forests of this type just north of Lang Hanh greatly impressed me during a visit early in 1961 (Cooling, 1967). The general appearance is that of mixed selection forest, for, in addition to roughly equal numbers of pines and hardwoods among the dominants, young seedlings and advanced growth of pines and hardwoods were also present in various stages of development. This mixed forest ranges over quite wide edaphic variations without noticeable effect upon the pines. The relative dominance and frequency of the various hardwood species altered to some extent, and quite noticeable changes took place in the understorey and ground flora according to the soil type. Ground flora became less luxuriant and much more sparse on poor compacted sandy soil.

The high and roughly equal stocking of pines and hardwoods in many of these mixed stands and the fact that regeneration of both comes up in profusion on the same area led to the conclusion that the two types of tree were rooting in different zones or else that they were making different demands upon the site (Cooling, 1967). To the north of Lang Hanh along the road to Dalat are quite extensive areas of mixed *P. merkusii* and *D. obtusifolius* on red soils over basalt, soil type 19 on Moormann's map (1961).

Comparison of the pine distribution map in Nguyen Kha's paper with the soil map shows that in the same region, but nearer to Lang Hanh, similar mixed forest occurs over sandstones and schists in areas corresponding to soil type 18, mainly red-yellow podsols.

The stands on red basaltic soil are noteworthy because they represent the only forests containing appreciable quantities of *P. merkusii* seen on apparently rich deep soil on the mainland of Southeast Asia. Nguyen Kha (1965) in discussing *P. merkusii* concludes that it is not particularly demanding as to physical properties but is



Plate 6.

Mixed *P. merkusii*/*Dipterocarpus obtusifolius* forest near Lang Hanh, 850 m altitude, near Dalat, S. Vietnam. Both species are present in all stages of growth from seedlings to mature trees in approximately equal numbers. Dominants up to 30 m tall.

Photo: Feb. 1961.

less tolerant in its chemical requirements. He notes that it is to be found on basalt, sandstone or schist but almost never on granite in Vietnam. The finest trees grow on the 'rich' red basaltic soils.

The success of pine in competition with hardwoods on rich soil is not in accord with the usual position unless some factor operates to the disadvantage of the hardwoods such as volcanism in Sumatra or fire killing out primary forest or its relics as in parts of Laos. Volcanism certainly does not apply in South Vietnam and although fire is an important factor in clearing primary forest there is no evidence that it operates selectively against fire-tolerant hardwoods such as Dipterocarpus obtusifolius with which P. merkusii is here associated and with which it is associated in some other countries as well. Climatic factors do not seem to offer an explanation either. Reference to the water balance diagram for Djiring (Fig. 2), the nearest available station to Lang Hanh, shows that the moisture deficit is much less marked than is the case in pine areas in Thailand and Cambodia. On this basis one would expect conditions on good sites to be even more in favour of hardwoods.

However, in view of the findings of Moormann (1961) and of Dudal and Moormann (1964) that the more acid red-brown latosols in particular are leached and lacking in nutrients, the anomaly may be more apparent than real. See also section 4.4 Soils. In his thesis Nguyen Kha (1965) has presented the results of physical and chemical analyses of several profiles on the basalts. These data show that the soils concerned are predominantly acid with pH values in the range 4.6 - 5.6 over the whole profile. The C/N ratios are high; exchange capacity (T value) is 20 or less - often under 10; and total exchangeable cations (S) are low, 6.9 - 1.4 in the A horizon and 1.8 - 0.35 in the B and B/C horizons. These pine-bearing latosols on basalt are, therefore, relatively infertile and appear to conform with the evaluation by Dudal and Moormann.

Nevertheless, Nguyen Kha has demonstrated that the growth of P. merkusii on the latosols is superior to that on the (podsollic) soils derived from sandstone or schist. (cf. 4.66 Rate of Growth).

4.622

Floristic Composition

Nguyen Kha (1965) quoting M. Schmid gives the following table of the more frequent species in P. merkusii forest:

Table 12

<u>Scientific Name</u>	<u>Family</u>	<u>Remarks</u>
Canopy:		
<u>Pinus merkusii</u> J. and de V.	Abietaceae	Dominant
<u>Dipterocarpus obtusifolius</u>	Dipterocarpaceae	Dominant
Understorey:		
<u>Pasania dealbata</u> H. and Cam.	Fagaceae	Abundant, nearly always present
<u>Quercus helferiana</u> DC.	Fagaceae	Fairly abundant
<u>Zizyphus rugosa</u> L.	Rhamnaceae	-
<u>Engelhardtia colebrookeana</u>	Juglandaceae	-
<u>Tristania burmanica</u> Griff.	Myrtaceae	-
<u>Symplocos</u> sp.	Symplocaceae	-
Low Vegetation:		
<u>Imperata cylindrica</u>	Gramineae	Forms the bulk of the herb mat
<u>Hyparrhenia filipendula</u>	Gramineae	-
<u>Polytoca heteroclita</u>	Gramineae	-
<u>Anisopappus chinensis</u>	Compositae	-
<u>Inula cappa</u>	Compositae	-
<u>Blumeopsis</u>	Compositae	-
<u>Vernonia saligna</u>	Compositae	-

In mixed P. merkusii/D. obtusifolius forest Dalbergia variensis and Albizia lebbakoides appear on the better soils while Shorea obtusa and Terminalia tomentosa occur on shallow soils. P. kesiya and Keteleeria davidiana become associated at higher altitudes.

4. 623

Stocking

The following information on stocking in the P. merkusii forest is taken from Nguyen Kha (1965). Stocking varies in density depending on whether pure or mixed pine forest is involved. Pure stands are rare but counts in the Forest Reserve of Dargna show a mean of 105 pine stems per hectare over 30 cms diameter, totalling 76 cubic metres in volume, out of a total of 80 cubic metres and 135 stems per acre for all

species and size classes. Counts in the more frequent mixed stands show, in the forest of Dangia, less than half this number of P. merkusii stems, i. e. 48 stems over 30 cms with a mean volume of 65 cubic metres per hectare. In the same area an average of 49 D. obtusifolius stems accounted for 48 cubic metres per hectare. Other species totaling 28 stems per hectare added a further 22 cubic metres. Contributions to the total volume on a percentage basis were thus:

<u>P. merkusii</u>	47.5%
<u>D. obtusifolius</u>	36%
Other species	16.5%

4.63 Growth Habits

P. merkusii of South Vietnam is a large straight-boled tree. It attains larger dimensions than P. kesiya and, according to Nguyen Kha, (1965), can live longer.

4.631 Size under Typical Conditions

Trees in the diameter range 30 to 40 cms and with heights between 25 and 33 m are fairly numerous. The boles of such trees are usually clean for about 10 to 15 metres. The largest tree measured by me in 1961 was 110 cms in diameter and about 30 m tall. Nguyen Kha quotes rare trees of 60 to 80 cms in diameter in old gardens.

4.632 Crown Shape and Branching

P. merkusii cleans itself well even in fairly open stands but the branches in the crown are moderately heavy and spreading. Branches are usually horizontal to slightly ascending in older trees and irregularly spaced. In younger trees they are strongly whorled and more ascending. The tree is decidedly uninodal (Nguyen Kha, 1965; Cooling, 1967). Counts of growth rings and branch whorls on five random trees in the younger age class made near Lang Hanh in 1967 confirm this.

Table 13

Relationship between numbers of branch whorls and growth rings,
Lang Hanh, Vietnam

Tree No.	No. of growth rings at 30 cms above ground	No. of whorls of branches above 30 cms	Total ht. in m
V1	17	17	7.3
V2	16	16	7.9
V4	15	15	7.6
V5	16	15	7.9
V7	17	17	8.2
Totals	81	80	38.7
Arithmetic mean	16	16	7.8

The average annual height growth of these trees thus appears to be 49 cms per year. In addition to the above trees one foxtail tree was examined and was found to have 14 or 15 growth rings, seven whorls of branches and to be 7.3 metres high. A very vigorous tree in an open position was found to have nineteen growth rings, seventeen whorls of branches and to be 15.8 m high, giving an average annual height increment of 83 cms.

4. 633

Bark

Bark on mature trees is dark reddish-brown in colour and deeply fissured into elongate angular plates. It is thick, averaging about 6 to 7 cms at breast height on large trees.

4. 634

Root System

P. merkusii has a strong root system comprising a vertical tap root and numerous laterals which branch again into horizontal, vertical and oblique roots, forming an efficient system for the exploration of soil in width and depth (Nguyen Kha, 1965).

4. 635

Cones and Male Flowers

P. merkusii fruits heavily at 20 years of age. Isolated trees come into bearing sooner, often in their tenth year (Nguyen Kha, 1965). Cones are solitary, in pairs or occasionally in threes. They project at right angles to the branch when nearing maturity and are not pendant as in P. kesiya. Nguyen Kha (1965) states that they are shortly stalked and persist for 'a long time on the branches'. This is at variance with my own observations. In Vietnam, as in other countries in Southeast Asia, P. merkusii cones, although retained on the tree for some time after seed fall, are commonly shed before next season. Only occasionally does one see empty cones of the previous crop among the current ripe ones. In this feature P. merkusii differs from P. kesiya, in which the cones do persist so that those of two or three different seasons may be found at the same time.

Mature cones measure 8-13 cms by 3-4 cms (Nguyen Kha, 1965). Measurements made on cones collected by me range from 8.5 cms-13.2 cms for length but from 6.5-8.6 for width, suggesting that Nguyen Kha is quoting the width of mature but unopened cones.

Seeds are shed annually in March to April although good seed years were said by the local field staff to alternate with poor ones. In mid-May, 1967, the majority of P. merkusii trees inspected had just shed their seeds. Most of the bigger trees bore heavy crops of cones which were positioned surprisingly close to the branch tips. There was no sign of immature green cones, nor of new conelets on these trees though some of the younger trees with lighter crops did have a succession of stages.

Male catkins are c 0.45 cms long x 0.5 cms wide. The pollen grains, slightly smaller than those of P. kesiya, are equipped with two small balloons. Measurement of 100 pollen grains from male catkins of mature trees gave a mean of 51 μ wide x 42 μ high (Nguyen Kha, 1965).

4. 636

Seed

Nguyen Kha describes the seed as very pale reddish-brown in colour and gives the following means derived from the measurement of 100 seeds from mature trees of normal development:

Length of seed	6.69 mm
Diameter of seed	3.81 mm
Length of wing	22.12 mm
Breadth of wing	5.10 mm
Mean weight of 1000 seeds	34.074 grams

There are c 30,000 seeds per kilogram or 13,600 per lb. The germination capacity of fresh seed is high and no serious loss of germination is experienced during the short time it is kept prior to use in local nurseries. However, P. merkusii seed from this region certainly does not stand export and many instances are known of large consignments, some sent by airfreight and others by sea, being valueless on arrival at destination as a result of almost total loss of viability. P. kesiya seed obtained at the same time usually retains its viability well and causes no difficulty.

4.64 Regeneration

4.641 Natural Regeneration

Natural regeneration was seen in a variety of conditions, ranging from fairly dense shade under a canopy of mixed pine/hardwood forest to open grassy glades. A slight gap in mixed forest was sufficient to enable regeneration to establish and to grow up into the main canopy. Regeneration of hardwoods, notably Dipterocarpus obtusifolius, responded in the same way so that pure crops of pine seedlings were unusual, except along forest margins against seasonally waterlogged depressions. P. merkusii tended to colonise the edges of these grassy depressions and especially any low promontories within them forming nearly pure stands but not attaining more than about 6 m in height and suffering much damage from late fires.

Apronounced grass stage is evident during which growth energy is directed to the development of a thick but short stem densely covered with long stout needles. Examination of many seedlings in different stages of growth suggests that, under natural conditions, the stem thickening commences in the second season and continues for two or three years during which time little height growth takes place. Height growth then commences (i. e. in the fourth or fifth year) and probably accelerates annually for some years. On average a five year old plant in natural forest is about 150 cms tall, having made most of its growth in the last year or two. Nguyen Kha quotes the following measurement made on young plants at Blao (assumed to have been grown in a nursery):

Age:	4 months	1 year	2 years	3 years	4 years	
Height:	7.5	12	22	75	116	cms
	(with an equally long taproot)					

Observations on natural regeneration under a mixed pine/ hardwoods stand just north of Lang Hanh showed that the presence or absence of established seedlings in the age classes 1 to 5 years was related to the passage of ground fires. Areas subjected to a strong burn during the last few years were but sparsely stocked with seedlings in these age classes, although newly germinated seedlings from the current crop were abundant. In parts of the forest, on the same soil, where there was no evidence of strong fire in the last few years, established seedlings in the younger age classes were far more abundant. Although the pines are not tightly grouped in these forests past fire is reflected by patches of regeneration of different ages.

4.642

Artificial Regeneration

Although P. kesiya has been planted quite extensively on the hills around Dalat no plantation of P. merkusii was seen in South Vietnam. Underplanting in fairly open D. obtusifolius forest near Lang Hanh was inspected in 1961 and appeared to be successful. P. kesiya had also been tried in the same area but did not survive. The plants used were raised to planting size in pots of clay or compressed earth. These pots have now been superseded by polythene bags. No advance site preparation was done: the pot plants were simply inserted into a small hole prepared at the time of planting. Spacing depended on the density of the forest and the stocking of the natural pine, the object being to increase the proportion of pine.

4.65

Silvicultural Treatment

As far as could be ascertained no silvicultural treatment has yet been undertaken in the P. merkusii stands apart from enrichment planting. It was felt that protective early burning throughout the pine stands plus an attempt at complete protection, or failing that, intensive patch burning in regeneration blocks for a period of four years would very materially assist regeneration in the pine forest.

4.66

Growth Rate

The following data on diameter increment demonstrating enhanced growth rates on basalt are quoted by Nguyen Kha (1965):

Table 14

Mean Annual Diameter Increment of P. merkusii in Relation to Geological Situation

Mean age (years)	Spot 1 on basalt	Spot 2 on basalt	Spot 3 on sandstone	Spot 4 on schist
5-15	.702 cm	.718 cm	.606 cm	.390 cm
15-25	.630	.640	.458	.412
25-35	.525	.532	.390	.370
35-45	.404	.412	.284	.340
45-55	.380	.388	.220	.292
55-65	.346	.302	.202	.336
65-75	.296	.260	.202	.280
75-85	.240	.220	.200	.228
85-95	.238	.234	.196	.246
95-105	.234	.220	.196	.232
105-115	.216	.212	.180	.220

It is evident from these data that there is a progressive drop in increment with increasing age.

Growth ring data for six young trees sampled by me near Lang Hanh on a grey/brown fine sandy soil are presented below:

Table 15

Tree No.	No. of growth rings at breast height	Radius in mm	Mean annual diameter increment cms	Remarks
V1	18	44.0	.489	
V2	20	73.0	.730 .487	(10 rings appear to be false)
V4	17	48.0	.565	
V5	17	41.4	.487	
V6	16	33.3	.416	
V7	14	37.0	.529	
Arithmetic mean			.54	Taking age of tree V2 as 20
			.50	Taking age of tree V2 as 30

Both values for mean annual diameter increment lie between those for basalt and sandstone in Table 14.

Comparison of the data for site 3 (sandstone) Table 14 above with Table 6 giving the annual diameter increment by age classes of P. merkusii on the sandstone plateau of Kirirom, Cambodia, reveals rather faster growth in the pure crop at Kirirom, particularly in the older age classes. The growth rate on basalt in Vietnam exceeds that at Kirirom for the first thirty-five years but then drops behind. On the basis of these data, trees in the 70-80 cm diameter range are likely to be to the order of 250 years old.

Height increment data are lacking. A very rough guide is available from the arithmetic mean tree of 7.8 m height at 16 years (Table 13). This compares with 6 m at 10 years and 14 m at 30 years at Kirirom (Table 8).

4.67

Injuries and Protection

4.671

Fire

By virtue of the grass stage in seedlings and thick bark and erect habit thereafter, P. merkusii in Vietnam is definitely fire-resistant.

Occasional live trees of large size found in the gardens of shifting cultivators prove that the species can withstand repeated fire (Nguyen Kha, 1965) as does its continued presence in the fire-prone 'forêt claire'.

Concluding his thesis on the P. kesiya and P. merkusii forests in Central Vietnam Nguyen Kha states "In the course of this study of the forests of P. khasya (P. kesiya) and P. merkusii it is apparent that fire plays a dominant role. It is the fires which favour the pines at the expense of the hardwoods. It is the clearings which upset the natural equilibrium and lead to secondary forest in the place of the original forest". However, he goes on to point out that the forester cannot rely on this blind force which is directly destructive, as well as having an indirect action on the structure of the forest and soil. The conifer forest is the result of clearing and burning, but it also risks being destroyed by the same processes.

4. 672

Shifting Cultivation

Various mountain tribes such as the Chils, Rhades, Mans and Muong are the indigenous inhabitants of the high plateau region of Haut-Donnai. They account for some 40,000 of the total population of about 76,000 in the region. But, whereas the more recent arrivals are concentrated into towns such as Dalat, with a population density of 400 people per sq. kilometre, the interior of the country occupied by the tribes has a density averaging only 4 per sq. kilometre. The principal agricultural method of the indigenous mountain tribes is shifting agriculture or 'rays'. This involves the felling of all woody material except for occasional very large trees. A little before the end of the dry season the felled material is burnt off to form an ash bed in which hill rice is sown. Up to three annual crops may be obtained from one site. A few other crops such as maize, sorghum and pumpkins are also grown in the same way. Once the soil becomes impoverished the family moves on to a new area and a period of fallow sets in, the duration of which would normally depend on the time needed for the forest to regenerate and restore fertility. This is not always the case since pressure of population may force a shortening of cycles. Decreasing yields and eventual serious soil degradation result.

The clearing of primary forest for shifting cultivation certainly creates conditions suitable for the spread of pines. Being a light-demanding species with wind dispersed seed and the ability to thrive on poor soil P. merkusii is able to take advantage of these conditions. It is well adapted to withstand periodic fire. In much of the region under consideration, therefore, it probably continues to extend at the expense of primary hardwood forest. However, the settlement of

refugees in more or less permanent camps in certain areas and the tendency for some mountain tribes to concentrate their gardening along the main road system for security reasons is creating a new situation in the affected area. The necessarily reduced fallow period, together with annual fire, is likely to reduce the establishment of pine very substantially indeed.

4. 673 Grazing

No information is available concerning the effect of grazing on P. merkusii but it is not thought to be a serious matter in Vietnam except near the larger centres of population.

4. 674 Wind

Observations by Nguyen Kha (1965) in Vietnam confirm that P. merkusii is a very wind firm species. No evidence of wind throw was seen but in view of exposure to at least the tail-end of typhoons from the South China Sea considerable wind stress must be suffered at times.

4. 675 Insect Pests

No evidence of damage to P. merkusii by shoot borers was seen in Vietnam and no indication was obtained of any other important insect pest of undamaged trees.

4. 676 Fungi

Fungi do not seem to be a serious threat to undamaged pines in Vietnam.

4. 68 Wood Properties and Uses

P. merkusii in Vietnam has a greater number of medullary rays, larger resin canals and longer fibres (about 7 mm) than P. kesiya (Nguyen Kha, 1965). He also states that the heartwood is more or less full of resin, having a dark red-brown colour, while the sapwood is a light yellow and often blue stained (presumably after felling).

The amount of resin is said to give the wood a certain stability with a lower total shrinkage than that of P. kesiya, but the wood is characteristically variable in physical properties.

Mechanical properties quoted by Nguyen Kha are as follows:

Crushing strength (Compression parallel to grain)	510 kilograms per sq. cm
Static Ratio $C/100D$	6.8
Specific ratio $C/100D^2$	10
Bending strength	1150 kilograms per sq. cm
Impact strength	0.320 kilograms
Dynamic ratio K/D^2	0.70

At 12% humidity density varies from 0.5 to 0.9, variation in density being mainly due to the amount of resin in the wood (Anon, 1954).

The following information on technological characteristics and uses is taken from an anonymous article on the Pines of Indo-China in *Bois et Forêts des Tropiques*, No. 35, May-June 1954:

Technological Characteristics: The wood is easily worked both by hand and by machine though light damage from sawing may occur due to the presence of resin. This can be cured by spraying the saw teeth with paraffin. This wood nails, glues and tongues and grooves in a perfect fashion. It generally takes paint and varnish without difficulty. However, the very resinous wood is more difficult to paint for the resin may exude again under the paint.

Uses: The wood of *P. merkusii* (and *P. kesiya*) resembles that of the French Maritime Pine or even certain types of *P. sylvestris*. It can be put to a great number of uses. In the mountainous regions where it grows it has been used for the construction of houses, frames, joinery, parquet, etc. At Tonkin the two-needed pine has for a long time been considered the best wood for carving and all the old buildings of Hanoi and Hai Phong have their carving, both interior and exterior, and their parquet of pine. The timber of the two-needed pine is particularly useful for construction purposes. Both timbers are equally useful for making boxes, matches (the less resinous young wood) and paper pulp (young wood). They also provide telegraph poles. The most resinous timber strongly resembles American pitch pine and is used in decoration.

4.69

Oleoresin

P. merkusii produces a good flow of high quality resin comparable with that from the Maritime Pines in France, (Anon, 1954). Tapping, which had for long been done on a small scale in the Tonkin forests, was

expanded in 1942 in the P. merkusii forests of Langbian to cover some 35,000 hectares. This exploitation was carried out methodically in the old stands, producing 10,000 tons of medium resin (Anon, 1954). But, by 1954 the production had dropped to only 227 tons due to the shortage of labour in the forests (Dahl, 1955). The system of tapping and the tools employed are the same as those used for Maritime Pine in France. Light tapping commences between 20 and 30 years of age when the tree is about 25 cms diameter, the tapping being limited to one or two cuts per tree according to diameter. Tapping intensity then increases to a maximum in the four years preceding felling when the tree has as many faces as it can take (gemmage a mort). The mean annual output per face is $\pm$ 5 kilograms or about 420 kilograms of resin per hectare from a well managed plantation.

Caution in the matter of tapping is evidently necessary. Nguyen Kha reports that tapping weakens the tree and reduces annual ring width to 2 mm or less: one must therefore choose between resin tapping and timber production. In his view the loss of timber due to resin tapping is not compensated for by the value of the resin. Since he poses the question of whether tapping is to continue under more technical management it is possible that he is referring to a situation in which tapping is carried out with little control, as may be the case under present circumstances.

4.70

Seed Availability

Owing to the extensive area of P. merkusii forest in readily accessible localities in the Central Highlands plus the added attraction of even more extensive P. kesiya stands, South Vietnam offers excellent scope for large-scale seed collecting. Suitable equipment and trained assistance would be essential and, as for other provenances of P. merkusii, a prerequisite is a better knowledge of seed physiology and storage requirements. Unfortunately, of course, the present situation prevents any effective action in this direction.

5.0

LAOS

5.1

General

Laos is a long, narrow, club-shaped country with the head lying in the northwest and the haft orientated northwest-southeast. In consequence it has a very long boundary with Thailand on the west (about 1600 kilometres) and an equally long one with north and south Vietnam on the east. Borders with Burma and China in the north and Cambodia in the south are much shorter. The Mekong forms the western boundary for a distance of over 800 kilometres and is an important element in the Lao economy and history. It is a vital means of communication.

Laos, apart from the Mekong valley and the relatively restricted plains, is predominantly a country of rugged mountains and forest. Though often steep and high (exceeding 2400 metres) the mountains are densely forested. An exception is found on richer volcanic soils as in parts of the Bolven Plateau where much clearing has been done for agriculture.

Rice culture is carried out in the Mekong and tributary valleys, while conditions suitable for animal husbandry exist at higher elevations. Shifting cultivation, 'rays', is practised over extensive areas of the forested land by the mountain tribes for the production of hill rice and other crops, including opium poppy.

5.2

Climate

In comparison with its neighbours, Thailand and Cambodia, and to a lesser extent Vietnam, Laos is lacking in extensive plains and alluvial flats. The mainly mountainous nature of the topography is reflected in the climate. In addition Laos is geographically nearer to the centre of continental extremes in Asia than are the countries to the south, which are influenced more by the equability of archipelagos.

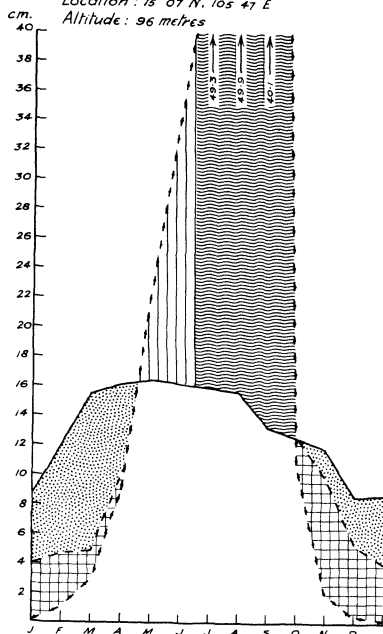
Precipitation is high along the main mountain chain in the south of the country. These mountains are in fact a continuation of the Annam Mountains of Vietnam. Much of this region receives over 2000 mm, while falls exceeding 3500 mm per annum occur in some of the higher ranges. Further to the north where the extensive uplands lie well away from the coast, rainfall is usually between 1000 to 2000 mm per annum.

Over most of Laos rainfall builds up rapidly from March; June to September are very wet, while October sees an abrupt decrease in precipitation to the dry season level which may vary from a few mm to

FIG.4. WATER BALANCE DIAGRAMS: LAOS.

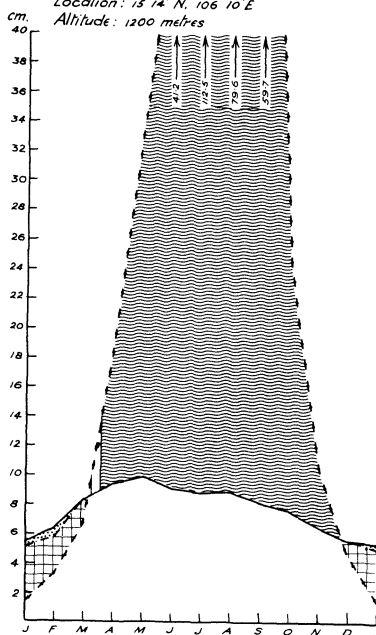
PAKSE, LAOS

Location: $15^{\circ}07'N$, $105^{\circ}47'E$
Altitude: 96 metres



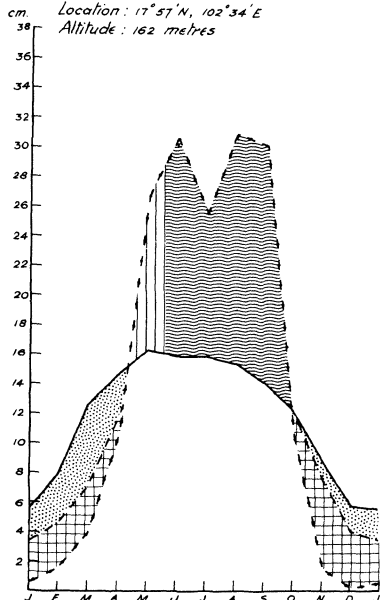
PAKSONG, LAOS

Location: $15^{\circ}14'N$, $106^{\circ}10'E$
Altitude: 1200 metres



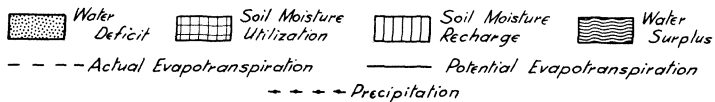
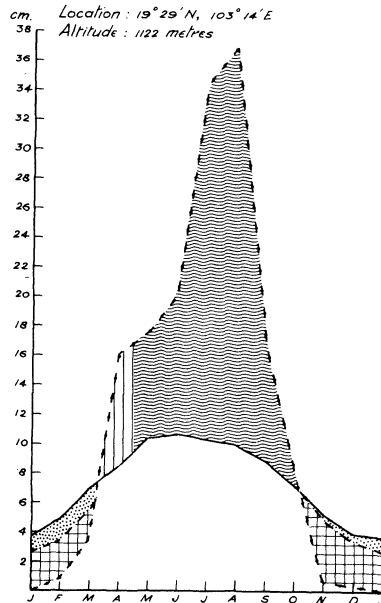
VIENTIANE, LAOS

Location: $17^{\circ}57'N$, $102^{\circ}34'E$
Altitude: 162 metres



XIENG KHOUANG, LAOS

Location: $19^{\circ}29'N$, $103^{\circ}14'E$
Altitude: 1122 metres



virtually nothing, depending on locality. The water balance diagrams (Fig. 4) illustrate the sharp peaks of precipitation very clearly. Relief exerts a strong influence on temperature and in consequence the uplands of Laos are sub-tropical with an average temperature of 18.3°C or less in the coolest month (January) and rising in April to an average of 23.9°C . Corresponding valley temperatures are 26.7°C and 29.4°C .

At Vientiane, 162 m, April is the hottest month, with an average maximum of 33.9°C and an average minimum of 22.8°C . The coolest month is January, when the temperature drops to an average maximum of 28.3°C and an average minimum of 13.9°C . The annual range of absolute maximum and minimum temperatures is from 40°C in March to 3.90°C in January. Luang Prabang, 286 m, has a slightly more extreme temperature regime, with an average maximum of 35.6°C in April and an average minimum of 20.6°C in the same month. In January the average maximum and minimum values are 27.8°C and 13.3°C , while the range in absolute maximum and minimum temperatures for the year is 45°C (April) to 0.6°C (January).

Being in the north of the Indo-China region the winter monsoon tends to become established in Laos by mid-September and lasts until March. However, wind direction is strongly affected by the mountainous topography and the two monsoons do not blow in their classic north-easterly and south-westerly directions throughout the land. The passage of shallow depressions during the course of the monsoons is more frequent in the north than in the south of the region and also results in less constant wind direction. Greater distance from oceanic influences emphasises the variability which, throughout the region, characterises the rains and the monthly totals of precipitation. Distance from the sea, however, has its compensations in much decreased liability to effect of typhoons from the South China Sea.

Humidity at Luang Prabang (286 m) at 10.00 hours varies little throughout the year. A low of 67% is reached in April and a high of 80% in August. Comparable figures at 16.00 hours reveal a greater range, being respectively 49% and 76%. For Vientiane (162 m) only the mean of the daily average humidity is available. This varies from a low 71% to a high of 87% in July.

Map 1 shows the higher peaks as Perhumid, while most of the elevated country is Humid, and the valleys Subhumid.

5.3

Physiography and Geology

The greater part of Laos comprises a mountainous area of diverse types of rock characterised by deeply cut valleys and steep

mountain crests. In the north these trend northeast - south west towards the Mekong but become northwest-southeast in orientation in the north-east. Further south the mountains constitute the Annam Cordilleras, along the watershed of which runs the boundary with Vietnam. In this region a fold/fracture structure involving sandstones and limestones predominates, but numerous other rock types are present. In the northeast the crystalline massifs and the extensive limestone areas form inaccessible blocks of country while old sandstone plateaux such as that at Tran Ninh southeast of Luang Prabang characterise the northwestern parts. Further to the south the Boloven Plateau is largely basaltic but upper Indochina Sedimentaries (Terrain rouge crétacé à Dinosauriens du Bas-Laos) are also shown on the geological map (Fromaget, 1952). Immediately to the south of the Boloven Plateau and extending down to the Cambodian border is a relatively large area of dacites, rhyolites and microgranites.

The alluvial flats of the upper Mekong are rather narrow on the Laotian side of the border with Thailand. The widest plains, usually associated with the junction of tributaries and the main river, are to be found in the vicinity of Vientiane, Savannakhet and in the extreme south along the Cambodian border. Geologically these flats comprise alluvia ranging in age from Quaternary to recent.

5.4 Soils

It has not been possible to obtain a general soil map or report covering Laos, and the areas visited and time spent in the country were too restricted for an appraisal of the soil, even of the pine areas only.

On the basis of the geology of the country (Fromaget, 1952) it is probable that the major soil types will be similar to those reported from Vietnam (Moormann, 1961). Podsolics and latosols are therefore likely to be of importance in the ecology of the pine. According to Vidal (1960a; 1960b) pines in Laos are characteristic of poor or degraded soils and areas subject to burning.

5.5 Forest Types

Due to the rugged topography, greater altitudinal range and generally more continental nature of the climate there is a greater complexity of vegetation in Laos than in Thailand or Cambodia for example.

Vidal (1960a; 1960b) has dealt in great detail with the vegetation and the forests of Laos. His classification of the forests is based on

the general ecological conditions. Six climatic zones are defined each with a corresponding climatic forest type. Associated with the climatic forests are other formations either transitory (secondary forests) or stabilized under the action of the soil (pseudo-climatic forests) or of man (peniclimatic forests).

The major forest types corresponding to the six climatic zones are:

- Zone 1 Closed-canopy moist semi-deciduous forest with dipterocarps
- Zone 2 Closed-canopy wet evergreen forest
- Zone 3 Closed-canopy moist semi-deciduous forest with Sapindaceae, Annonaceae, Meliaceae and Palmaceae
- Zones 4 & 5 Closed-canopy moist forest with Fagaceae, Lauraceae
- Zone 6 Closed-canopy moist forest with broad-leaved species and conifers

Vidal emphasises that the scheme is very general and that other factors such as the nature of the soil and the action of man are of vital importance. Due to the influence of edaphic and anthropic factors the main forest types do not correspond exactly to the various climatic zones. For convenience, therefore, the forests are divided into two groups, (a) lowland forests (Zones 1, 2 and 3) and (b) upland forests (Zones 4, 5 and 6).

5.51

Lowland Forests

- (i) Closed-canopy moist semi-deciduous forest with dipterocarps

Dipterocarpus elatus and Anisoptera robusta 40 to 50 m tall are emergent over other Dipterocarps, Leguminosae, Meliaceae, Sapindaceae and Lythraceae.

- (ii) Other types of closed-canopy moist forest

These include forests very similar to (i), but lacking the characteristic D. alatus; others in which D. costatus and Hopea odorata dominate and certain Zone 3 forests on the slopes of calcareous massifs, and also on alluvium, in which Sapindaceae (Nephelium, Pometia, Sapindus), Anonaceae and Meliaceae predominate.

(iii) Secondary Formations

These are chiefly characterised by pioneer species which colonise exploited or devastated climax forest. Typical species include Tetrameles nudiflora, Bambusa tulda, the herb Eupatorium odoratum, Trema, Mallotus, Alanthus, Anthocephalus, Macaranga, Broussonetia, etc.

(iv) Open Forest with Dipterocarps (corresponds to deciduous dipterocarp)

These are frequent in Zone 1, particularly to the east of Savannakhet. On physiognomic grounds they are divisible into (1) Scrub Forest, in which Pentacme siamensis, Shorea obtusa, D. intricatus, D. tuberculatus and Terminalia tomentosa predominate and (2) Closed Forest comprising D. tuberculatus and D. obtusifolius.

(v) Mixed Deciduous Forest

Less well defined than the preceding types it sometimes has affinities with closed and sometimes with open forest. On the whole it has three strata, trees, shrubs and grass, characterised by a number of species such as Pahudia, Xylia, Bombax, Lagerstroemia, Terminalia, Pterocarpus and, in the region of Paklay, Tectona. Clumps of bamboos are often present in the undergrowth which is otherwise dominated by Imperata cylindrica. This forest contains a high proportion of deciduous species.

(vi) Forest with Teak

In Laos natural Teak forests are met with in two regions in Zone 3. One on the right bank of the Mekong in the region of Paklay below Luang Prabang and the other on the left bank upstream of Ban Houey Say.

(vii) Savanna

Grasslands with varying stocking of widely spaced woody species: in most cases a result of the degradation of open or mixed deciduous forest following exploitation or repeated fire, but sometimes due to inundation or a combination of wet season flooding and dry season fire.

5. 52

Upland Forests

(i) Closed Forests

From an altitude of some 800 metres upwards to about

2000 metres closed-canopy moist forest is encountered which is characterised by the abundance of Fagaceae (Castanopsis, Lithocarpus, Pasania, Quercus) and Lauraceae (Cinnamomum, Litsea, Machilus). Despite the presence of a high proportion of deciduous species the general aspect remains evergreen.

At about 2000 metres (Zone 6) in the region of Xieng-Khouang closed forest consisting of mixed hardwoods and conifers is encountered on spongy humic soil. Fokienia hodginsii is found with Castanopsis, Mangletia and Elaeocarpus. The high humidity of this Zone is evident from the presence of lichens and moss on the trunks and Selaginella on the ground.

(ii) Open Forest

Among the open forests one may distinguish as in the lowland forests some péniclimatic forests due to degradation and some pseudo-climatic forests in which the influence of soil appears to predominate. Amongst these latter are the open forests with Quercus and Keteleeria. This type is very variable in appearance, ranging from tall well-grown forest to stunted scrub. The ground cover consists mainly of grasses and is regularly burned. Anthropic activity is also very evident.

(iii) Conifer Forests

There are two major types of conifer forests (a) open forest on poor soil on schists and sandstone; P. merkusii up to about 1000 metres, Pinus kesiya and Keteleeria roulettii from 800 to 1500 metres and (b) moist closed forest on deep soils from 1600 metres upwards, Fokienia hodginsii and Cunninghamia sinensis.

In general Pinus merkusii is found on the plains and up to about 800 metres, where it is replaced by P. kesiya. Keteleeria, sometimes pure, sometimes mixed with pines or with oaks, may also occur. Because the conifers have the capacity to colonise poor or exhausted soils they fulfil the role of pioneers in the reconstitution of devastated forest. The pines establish themselves first in the pseudo-steppe then there follows Keteleeria and hardwoods such as Pieris, Tristania and Schima. The pines then disappear, being replaced by oaks which proliferate, eliminating the Keteleerias and finally constituting almost entirely the woody element of the open woodland. This succession is generally interrupted by the action of man (through fire and grazing). The result is a state of dynamic equilibrium which often stabilizes the forests as open coniferous stands.

(iv) **Secondary and Degraded Forest**

The mountain areas are inhabited by Meo and Kha tribes and in consequence of their clearing by fire, 'rays', for purposes of cultivation, the only primary forest left is on inaccessible summits. The closed forest generally contains secondary pioneers in the holes caused by clearing. Where the forest has been totally destroyed by fire followed by cultivation the bare area is first invaded by a composite analagous to Eupatorium and also by wild bananas and high grass. There then follows a succession of species such as Croton, Trema, Macaranga and Alchornea.

5. 6 P. merkusii in Laos

5. 61 Distribution and Extent

Vidal (1960a) gives the following details of the distribution of P. merkusii in Laos:

Zone 1

- | | | |
|-------|---|-----------|
| (i) | Vicinity of Ban Na Khao between km 40 on the road Vientiane-Paksane and Nam Ngum
(Source: Forest Service Archives) | ? |
| (ii) | Between km 93 and 94 on road 13 north of Pakse (Source: Nouthak, 1943) | ? |
| (iii) | Between Houei Kadam and Ban Chak in the region of Khong (Source: Niquet, 1923) | 1, 000 ha |

Zone 2

- | | | |
|------|--|---|
| (iv) | In the vicinity of Ta Nok, 600 m a. s. l. on the sandstone plateau of Ta Hoi mixed with <u>Dipterocarpus obtusifolius</u> (Source: Niquet, 1923) | ? |
|------|--|---|

Zone 3

- | | | |
|------|---|-------------|
| (v) | Sandstone plateau of Nakai, northeast of Thakhek (Source: Niquet, 1922) | 80, 000 ha |
| | " " " (Source: Macey, 1908) | 100, 000 ha |
| (vi) | Phou Khao Kouay sandstone mountain north-east of Vientiane 700 m a. s. l. (Source: Forbé, 1942) | 2, 500 ha |

Zone 4

- (vii) Valley of the Nam San Noy east of Xieng-Khouang
(Source: Thao Phat, 1943) ?
- (viii) In the region of Muong Ou Neua, north of Phong
Saly (Source: Niquet, 1922) 10,000 ha

Zone 5

- (ix) Phou mai Pêk west of Paksong (100 stems per
hectare) (Source: Forbê, 1942) 200 ha
- (x) Summit of Phou Set (Source: Forest Service
Archives) ?

5.62

Description of *P. merkusii* Forest

Only three localities were briefly visited by me during a necessarily short stay in Laos. The forests at two of these are described later in this section. The general description of *P. merkusii* forest in Laos which now follows is based on Vidal (1960a).

In certain localities this pine forms pure crops not differing in general appearance from stands in Europe. On the plateau of Ta Hoi it is associated with *Dipterocarpus obtusifolius*, as it is near Dalat in South Vietnam. On the plateau of Nakai *Keteleeria* and *Quercus* are found as well. These species form open stands in which islands of pine are scattered in a vast pseudo-steppe, similar to that of Tran Ninh. In the depressions with clay soil bamboo becomes established and has a tendency to take over the underwood of the pine forest, preventing pine regeneration. The different localities in which *P. merkusii* is to be found show that this species is capable of growing under a wide range of conditions: Vidal's Zones 1 to 5. However, it is always established on poor soils, subskeletal or degraded, where other species have difficulty in asserting themselves. If soil conditions improve, and in particular if there are not repeated fires, the pine forest can be invaded by other trees and shrubs and develop imperceptibly towards a closed formation. However, it seems that the forest may be held in its present state by the annual passage of fires and that it may be considered a péniclimax (? pre-climax). *P. merkusii* forest in Laos is thus an open forest or woodland formation (forêt claire) found in Zones 1 to 5 on sub-skeletal or degraded sandstone and schist soils.

Done Xang Phay Forest some 42 km from Vientiane on the main road to Paksane and then about 4 km northwest on a bush track was visited in May 1967. Altitude is some 360 m and the particular area

of pine bearing forest seen was about 0.7 by 1.5 km in size. Mature and overmature pines were associated with moist semi-deciduous forest, including Dipterocarps and with clumps of bamboo and climbers. Both pines and hardwoods reach considerable size, dominants being well over 100 feet high. Although mixed with hardwoods, P. merkusii constitutes about two thirds of the dominants in the areas in which it occurs.

No saplings or pole stage growth was seen. This was said to be due to annual severe fires which kill out the younger trees. There is much gardening, and, more recently, logging in the area. Current year's seedlings are occasional only; there was no sign of any older ones.

A second area of pine-bearing forest was visited in the vicinity of Khong Sedone. This lay to the west of the main road to Bung Sai and Saravane at about 35 km from Khong Sedone. The altitude was approximately 425 m. The pines were present in open grassy glades in forest which varies from dense, well-stocked evergreen, to a relatively open semi-deciduous or deciduous type, possibly a secondary formation. The pines were inclined to be grouped but in parts the stocking was fairly uniform. Over the pine areas as a whole the distribution of size classes seemed reasonable except for trees under about 10 to 15 years old. Part of the pine area adjoins or possibly enters the Phou Xieng Thong Forest Reserve which contains tropical rain forest still dense despite exploitation to a 40 cm girth limit. Part of the reason for this is the presence of resin and gum-producing species, often old and very large, which are individually owned and may not be cut even on F.D. licence without the consent of the owner. This forest is also a game reserve said to have tiger, bantang and deer.

The soil in the open glades appears to be mainly a pallid, silty sand. Some outcrops of fine sandstone were noticed in stream beds but the geology of the area was not ascertained. Under the best evergreen forest the soil was found in places to be a yellow/orange clay sand. The stronger hued and less sandy soil exhibited more undulating and broken relief and might be associated with the lower slopes of weathered and truncated foothills of a range which the heavy forest appeared to parallel.

The occurrence of pine vis-a-vis hardwoods seemed to be linked partly to edaphic conditions and partly to anthropic activity. Much of the pine occurred in open glades. These glades were in the form of ribbons and fingers of almost pure pine with a grassy (Imperata) or sometimes a shrubby ground cover in a matrix of hardwood forest. The terrain was generally level but sometimes the impression was gained that the pine was on the site of seasonal drainage channels

rather like the 'dambos' of central Africa but not nearly so well developed. The pine glades were usually narrow, often only a few metres wide, but extending up to a kilometre or more in length. Other pine stands, irregular in outline and not necessarily attenuated seem to have established themselves in man-made clearings in the forest and, in such localities, secondary or open deciduous forest was usually in evidence.

Although Paksong on the Boloven Plateau was visited it was not possible to go to the actual pine stands in that area. Fragmentary specimens said to be of P. merkusii were obtained from the forest which was reported to be on volcanic slopes about 13 kilometres northwest of Paksong and extending northwards. The pine was said to grow in pure groups among the hardwoods as at Phou Xieng Thong. The specimens, certainly of a two-needled pine, do not correspond well with other P. merkusii material but may be atypical.

5.63

Growth Habits

At both Done Xang Phay and near Khong Sedone the P. merkusii stands were impressive in size and stem form. Some stem sweep was evident on pines in competition with large hardwoods.

5.631

Size under Typical Conditions

At Done Xang Phay heights of dominants were estimated to range between 30 and 40 metres. Measured diameters also on dominants and co-dominants ranged from 60 to 80 cms. In the forest 35 kilometres from Khong Sedone, Phou Xieng Thong, measured heights and diameters ranged between 28 and 41 metres and 50 and 85 cms respectively. The majority of dominant stems were clear of branches for 15 to 20 metres.

5.632

Crown Shape and Branching

Young trees exhibit good apical dominance and crown shape is pyramidal. Older trees develop a rounded crown. Branching is light to moderate on young trees but definitely uninodal. Older trees develop less regularly spaced, heavier branches but crowns are seldom really heavy, probably due to competition from tall hardwoods.

A comparison of growth rings and number of branch whorls on five random trees from an apparently even-aged group near Phou Xieng Thong gave the following results:

Table 16

Relationship between numbers of branch whorls and growth rings,
Phou Xieng Thong, Laos

Tree No.	Number of Growth Rings	Number of Branch Whorls	Total ht. metres
L11	19	20	14.3
L12	21	21	16.1
L13	21	21	14.0
L14	20	19	9.4
L15	21	19	12.5
Totals	102	100	66.3
Arithmetic mean	20	20	13.3

Assuming growth rings to be annual the average height increment of these five trees is thus 66 cms and branching in the younger trees is strongly uninodal.

5.633

Bark

Considerable variation in the pattern of bark cracking was observed in the forest at Phou Xieng Thong. Some trees had strongly ridged bark with deep vertical fissures and relatively weak horizontal cracks. Others had the bark divided into angular plates by a reticulate pattern of cracking. Intermediate types were noticed and some trees displayed both patterns. The reticulate pattern was found most commonly on trees standing in grass and obviously exposed to frequent fire damage. Trees in more sheltered situations, as for example those in small gaps in the evergreen forest, almost invariably had thick vertically ridged bark, often with thin, loose, superficial scales. It thus appears that fire causes the loss of part at least of the outer ridged bark and either exposes or initiates the reticulate pattern of cracking. Insolation may be another factor involved. The effect of fire on the bark pattern of P. merkusii thus appears analogous to that of fire on P. kesiya bark (Cooling, 1967, p. 8).

All the P. merkusii bark examined was thick, to the order of 6 cms or more at breast height on a large tree. Even if fire had caused severe exfoliation the remaining bark was seldom less than 4 cms thick.

5. 634 Root System

No root systems were examined.

5. 635 Cones and Male Flowers

Owing to the great size and clear boles of the majority of trees and lack of climbing equipment it was not possible to obtain fresh cones. Twenty fallen cones were collected at Phou Xieng Thong and averaged 7.6 cms in length; range 6.2-9.4 cms. Twenty-five cones collected from the ground at Done Xang Phay averaged 8.0 cms in length; range 6.5-9.3 cms.

Cones are borne in ones, twos and threes high in the crown. They project from the branch at right angles in typical P. merkusii fashion. The cones are shed soon after seed fall and do not persist on the tree to the following season.

5. 636 Seed

No seed was collected due to lack of time and equipment, and none was available from the Forest Service.

5. 64 Regeneration

5. 641 Natural Regeneration

A short account of Vidal's description of P. merkusii in Laos and its general ecological status has been given in Section 5. 62. It is clear from his studies that fire and cultivation assist the spread of pine into areas previously occupied by hardwood forest.

Observations by me in the course of very brief visits to only two localities suggest however that excessive fire may greatly retard the spread of pine, or even eliminate it.

At Done Xang Phay no seedlings more than a few months old could be found; all those seen had germinated since the previous dry season. There was a complete gap in age classes between these and trees of moderate size assumed to be twenty to thirty years old. The lack of younger size classes was said to be due to severe annual fire.

The position at Phou Xieng Thong was a little better because sparse regeneration could be found in the grass of the pine glades. The destructive role of fire was indicated by the greater number of seedlings in relatively protected situations such as small enclaves of grassland between evergreen forest and pathways.

Typical grass stage seedlings with short thick stems were seen at Phou Xieng Thong, although seedlings in protected positions near the hardwood forest tended to be thinner and more attenuated than usual.

5. 642 Artificial Regeneration

The Forest Service in Laos has not yet undertaken any large-scale planting of P. merkusii. A small number of plants have been raised by one or two interested officers. These were not seen but were said to pass through a grass stage despite adequate watering.

5. 65 Silvicultural Treatment

No silvicultural operations were seen in P. merkusii forest in Laos.

5. 66 Rate of Growth

Published data are not available for P. merkusii in Laos.

A very rough estimate of growth rates in Done Xang Phay and Phou Xieng Thong may be made on the basis of increment cores taken in these two forests in May 1967. (See Table 17)

Table 17

Mean annual diameter increment determined on 4 mm increment cores. Dominants and Co-dominants

Origin	Tree No. Dimensions	No. of Rings	Width (mm)	Running Total (mm)	Mean annual diameter increment (cms)	Mean annual diameter increment full core (cms)	Remarks
Khong Sedone N. B. These are all dominants or co- dominants of large size. Length of increment cores is not related to tree diameter	L6	0-20	25.3	25.3	.25	.34	Reading from bark toward pith 11 rings assumed false
	D. b. h.	21-40	30.3	55.6	.30		
	84 cms	41-60	32.6	88.2	.33		
	Ht.	61-80	44.8	133.0	.45		
	40 m	81-83	9.7	142.7	.65	.23	Reading from bark toward pith 12 rings assumed false
	L7	0-20	10.2	10.25	.10		
	D. b. h.	21-40	14.8	25.1	.15		
	63 cms	41-60	11.1	36.2	.11		
	Ht.	61-80	16.6	52.8	.17		
	37 m	81-100	33.0	85.8	.33	.25	Reading from bark toward pith 4 rings assumed false
		101-111	40.7	126.4	.74		
	L8	0-20	21.4	21.38	.21		
	D. b. h.	21-40	19.6	41.0	.20		
	49 cms	41-60	18.0	59.0	.18	.22	Reading from bark toward pith 5 rings assumed false
	Ht.	61-80	22.0	81.0	.22		
	28 m	81-100	43.5	124.5	.43		
		101-102	4.4	129.0	.44		
	L9	0-20	17.6	17.65	.18	.34	Reading from bark toward pith 17 rings assumed false
	D. b. h.	21-40	18.0	35.7	.18		
	56 cms	41-60	22.9	58.6	.23		
	Ht.	61-80	23.7	82.3	.24		
	34 m	81-90	18.9	101.1	.39	.34	Reading from bark toward pith 17 rings assumed false
	L10	0-20	19.0	19.0	.19		
	D. b. h.	21-40	44.4	63.4	.44		
	81 cms	41-60	38.7	102.1	.39		
	Ht.	61-74	23.5	125.6	.34		
	41 m						

Current mean annual diameter increment at .1 to .25 cm is very poor and confirms the field impression of over-maturity. All trees show a decrease in growth rate over the core length sampled (10-15 cms). Some 80 to 100 years (rings) ago growth was appreciably better, ranging from about .35-.75 mm. On the basis of tree diameters, and numbers of growth rings in the lengths of cores sampled, it is very likely that the dominants are 200-250 years old.

In addition to the five dominants above, five trees were taken at random in an apparently even-aged group in a fire-protected locality against heavy rain-forest margin. Results are presented in Table 18:

Table 18

Mean annual diameter increment determined on 4 mm
increment cores: Young trees

Origin	Tree No.	No. of Rings	Radius in mm	Mean annual diameter increment (cms)
Phou Xieng Thong Forest, Khong Sedone, Laos	L11	19	51.25	.51
	L12	23	58.63	.51
	L13	25	40.00	.32
	L14	26	34.75	.27
	L15	20	51.00	.51

5. 67 Injuries and Protection

5. 671 Fire

As stated in Section 5. 641 Natural Regeneration, fire is believed to be responsible for the paucity of regeneration and of the younger age classes in the crops visited but there was no evidence that P. merkusii in Laos is appreciably less fire-hardy than the provenances in Thailand for example. Attenuated plants on the edge of hardwood forest would suffer more damage from a fire than tufted plants in open grassy areas but the risk of fire is correspondingly lower. Differences in the degree of grass stage development are believed to be purely phenotypic.

Serious fire damage to the Phou Xieng Thong pine is thought to be a more recent development than at Done Xan Phay. Saplings and pole stage trees are reasonably well represented in the former forest. The increase in damage now may be due to improved access via extraction routes in the adjoining hardwood forest and to the loss of strict Forest Service control since about 1960 owing to the political situation. Effective patrolling is difficult due to security risk.

Resin tapping is undoubtedly responsible for the loss of many fine dominants because the basal scars permit fire to gain a hold on the lower trunk. Successive fire eventually eats through the base of the tree. Apart from this, large trees are very resistant.

In their survey of the pulpwood resources of the lower Mekong Bryde et al (1965) although unable to visit the pine areas, state that 'the condition of the forest is reported to be bad, particularly as a result of fire damage'.

5. 672 Shifting Cultivation

It is considered that the role of shifting cultivation in the ecology of P. merkusii in Laos is similar to that in other parts of Southeast Asia, such as Thailand and Cambodia. The burning of 'rays' or gardens and their abandonment when exhausted, favours the spread of pine (both species) except on the deeper, inherently fertile soils. But intensive gardening with short cycles of clearing and associated annual fire may seriously reduce pine regeneration and survival.

5. 673 Grazing

No data were obtained regarding the effect of grazing on pines in Laos.

5. 674 Wind

The only wind-thrown trees noted had been damaged at the base by fire following resin tapping.

5. 675 Insect Pests

No information available: shoot borers were not in evidence.

5. 676 Fungi

Incidence and importance not known.

5.68

Wood Properties and Uses

No information could be obtained in Laos concerning the property and uses of P. merkusii in that country. So far as could be ascertained it is not exploited on an organised basis at present.

From the examination of fallen trees and of increment cores at Done Xang Phay and at Phou Xieng Thong the timber in Laos resembles that seen in Cambodia and other parts of the Southeast Asian mainland.

Growth rings are pronounced and apparently annual (See Section 5.67). Density determination on 15 increment cores gave the following results on the basis of saturated volume and oven-dry weight:

1. Done Xang Phay	Mature trees	Average density of 5 cores	0.57
2. Phou Xieng Thong	Mature trees	Average density of 5 cores	0.55
3. Phou Xieng Thong	Young trees about 20 years old	Average density of 5 cores	0.49

5.69

Oleoresin

Tapping is carried out quite extensively by villagers to obtain material for torch making but tapping for the commercial distillation of turpentine and the production of rosin is not done. Due to the security situation the Forest Service finds it extremely difficult if not impossible to exercise control over tapping by local villagers and considerable damage is undoubtedly being caused to the growing stock by the crude methods employed and by subsequent fire damage.

5.70

Seed Availability

Laos cannot be considered to offer good prospects for the supply of seed at present. Access to many parts of the country is restricted. The Forest Service has not embarked on any major scheme of afforestation with softwoods. There are thus no local facilities for the cold storage of conifer seed, nor is tree-climbing equipment available.

6.0

INDONESIA

6.1

General

Indonesia is the world's largest archipelago: some 7900 islands are included in its total extent, which, from east to west is about 3000 miles. In latitude Indonesia stretches from 5° North to 10° South.

Java is very heavily populated in relation to its size. Somewhat under 70,000,000 people (Dobbie, 1965) live on this fertile volcanic island which represents under 10% of the land area of the whole Republic.

Sumatra, although a much larger island than Java, has a far smaller population amounting to some 464,400 people in the 1961 census (Dobbie, 1965).

6.2

Climate

Although a relatively large island, Sumatra is small enough for the interchange of air with the surrounding sea to ensure the dominance of an equatorial, oceanic climate. The same considerations apply with greater force to Java. Consequently the chief climatic characteristics are abundant rainfall, light winds, high temperature and high humidity (Braak, 1945). The region is subject to a typical monsoon regime but the climatic changes are more pronounced in the south of Java than in Sumatra. There are two monsoon periods: the dry which lasts from about May to September, and the wet which lasts from about October to April. The mountainous interior experiences modifications due principally to altitude and the effect of wind direction in determining precipitation and cloudiness. In general the greatest climatic variation is in rainfall, although the average is high. Lack of the disturbances associated with the low pressure systems of higher latitudes results in little variation in air pressure and the relative absence of strong winds. Destructive cyclones are virtually unknown.

Rainfall throughout the archipelago is abundant. According to Braak (1945) the greater part of the mountainous region receives more than 3000 mm a year and over 2000 mm falls in large areas of the coastal plain. The whole island is either Humid or Perhumid on the Thornthwaite classification, see Map 1.

Very heavy falls of rain are experienced when the moisture-laden monsoon winds impinge on mountain slopes and in such situations rainfall may exceed 1000 mm in the wettest month. On some mountainsides exceptional falls in excess of 350 mm in 24 hours have in fact been

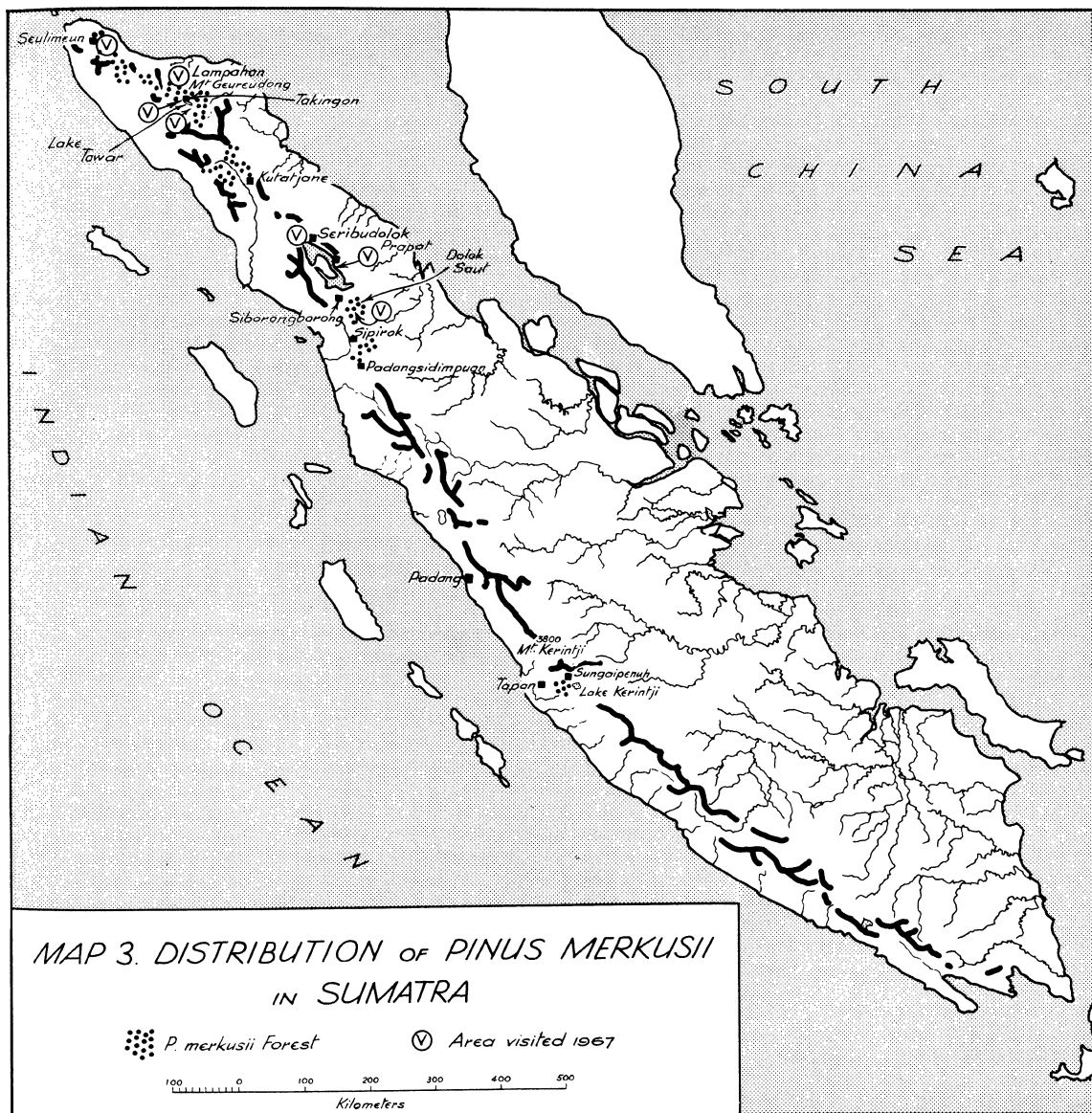
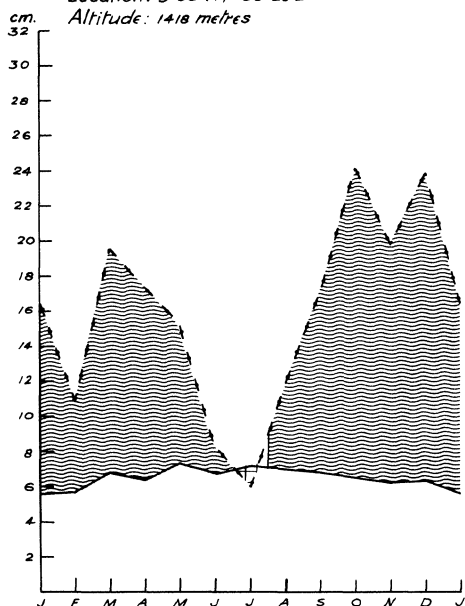


FIG 5. WATER BALANCE DIAGRAMS: INDONESIA.

SERIBUDOLOK, SUMATRA

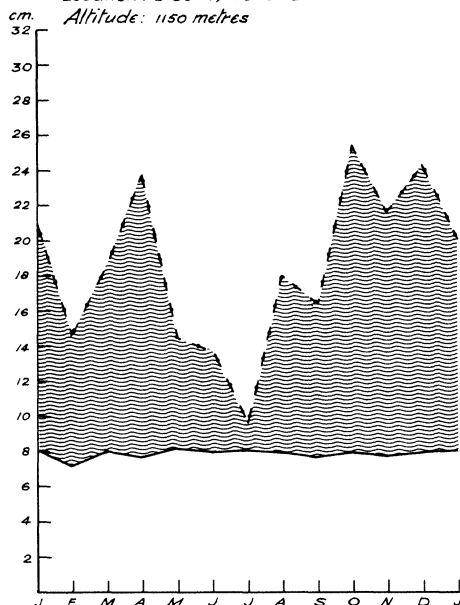
Location: $3^{\circ}00'N$, $98^{\circ}25'E$
Altitude: 1418 metres



Water Deficit
 Soil Moisture Utilization
 Soil Moisture Recharge
 Water Surplus
 - - - - Actual Evapotranspiration ——— Potential Evapotranspiration
 - - - - - Precipitation

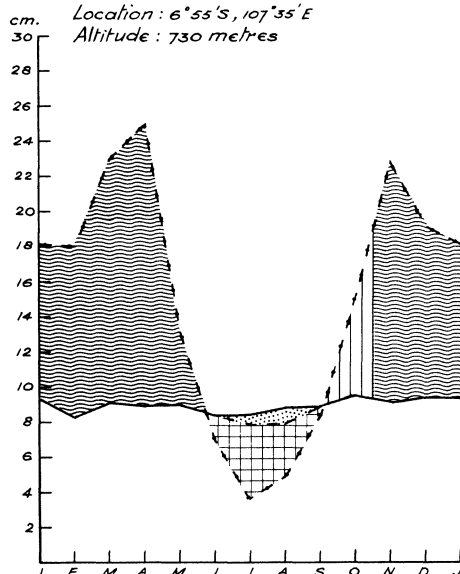
TOBA, SUMATRA

Location: $2^{\circ}30'N$, $99^{\circ}00'E$
Altitude: 1150 metres



BANDUNG, JAVA

Location: $6^{\circ}55'S$, $107^{\circ}35'E$
Altitude: 730 metres



recorded. The influence of the monsoons is not uniform throughout the length of the island chain. There is a definite dry season with moisture deficit in the east of Java, whereas most stations in Sumatra and the west of Java, although experiencing a seasonal variation in rainfall, do not have any completely dry month in the year and mostly have precipitation in excess of 100 mm in the 'dry' months. See water balance diagrams, Fig. 5.

While there may not be a dry month in certain localities in Sumatra when monthly rainfall averages are considered over a period of years, this is due in some cases to marked seasonal variation in rainfall distribution. In order to demonstrate this effect Schmidt and Ferguson (1951) have prepared a map of rainfall types in Indonesia based on wet and dry period ratios. The ratio has the form:

$$Q = \frac{\text{Av. no. dry months}}{\text{Av. no. wet months}} \times 100\%$$

A month is taken as 'dry' when the total rainfall is less than 60 mm and 'wet' when the total exceeds 100 mm. By average number of wet and of dry months is understood the actual averages of such months in successive years. These numbers do not correspond to the number of months which, on the average monthly rainfall over a period of years, are found to be 'wet on the average' or 'dry on the average'. Because the dry season does not always occur in the same month of the year the actual average number of dry months is generally higher than is apparent from the average monthly rainfall figures. On this basis virtually all the pine-bearing areas in Sumatra are seen to occur in rainfall type B ($Q = 14.3$ to 33.3%) whereas by far the greater part of the island receives type A rainfall ($Q = 0 - 14.3\%$).

Thunderstorms are an important feature especially in the mountainous regions. Most of these are heat thunderstorms, are short-lived and of relatively small extension. At Bogor, for example, Braak (1945) reports that thunder may be heard on 322 days in the year, in the majority of instances between 5 and 6 in the afternoon. He notes also that every year some of the trees in the Botanic Gardens are struck by lightning but do not die.

The average annual temperature at sea level in Java and Sumatra is a little over 26°C with only very slight deviations for the different stations; it is relatively constant throughout the year as well. The highest temperatures, about 27.5°C , occur on the north coast of east Java in November, towards the end of the dry season, while the lowest temperatures, about 25°C , occur in the southeast in July. Generally speaking the mean temperature of stations in the mountains can be calculated with good precision on the basis of a drop in temperature

of 0.6°C for every 100 m in height.

The day to day as well as seasonal variation in temperature is also low: the principal temperature variation is diurnal. At Bandung for instance the average oscillation for the whole year is 9.3°C . Braak (1945) states that the highest recorded temperature, 38.6°C in October, was observed at Sawahan in Central Java and the lowest - 2°C on the high plateau of Pengalengan (1550 m) in the dry season. Mean monthly values of relative humidity do not vary greatly and lie in the main between about 85% and 95%, except in those few areas with a pronounced dry season, where values for the driest month may drop to between 60% and 70%.

6.3

Physiography and Geology

According to Stauffer (1945) practically all the Indonesian islands are situated in the zone of the Alpine/Himalayan geosyncline which occupies roughly the area of the ancient Tethys Sea. This zone is a belt of labile equilibrium and relative weakness in the earth's crust and it is bounded on the north by the highly rigid mass of Eurasian shield and on the south by the Gondwana block. Horizontal movements from Cretaceous time to the present and of considerable but unequal magnitude, have affected large areas of the solid crust and exerted tremendous pressure on the geosyncline. Lateral compression has resulted in the formation of mountain chains accompanied by extensive folding, overthrusting and the appearance of numerous volcanoes. The Indonesian islands present a youthful stage of the orogenic process with mountains of relatively low altitude and numerous active volcanoes.

In this description only Sumatra and Java of the Indonesian islands are dealt with. The former because it is the natural habitat of P. merkusii and the latter in view of the extensive plantations of that species. The details of physiography draw much from the account by Dobbie (1965).

6.31

Sumatra

The island of Sumatra straddles the equator and is some 2600 kilometres in length, stretching from just under 6° North to nearly 6° South. It is about 190 kilometres across in the northern third but widens to an average of some 390 kilometres in the southern two-thirds of its length. A huge alluvial flat extends along the east of the island from a point somewhat south of Medan to the southernmost tip at Peluk Betung. This forest and swamp covered lowland, as Dobbie (1965) points out, is the longest and most continuous example of Southeast Asian equatorial

swamp still beyond the control of human technology. In places the swampy flat is as much as 240 kilometres wide and acts as a barrier to settlement and access to the interior.

A continuous range of mountains extends from Banda Atjeh in the north to Peluk Betung in the south. In the north of the country the range lies a little to the west of a central position but from about the level of Medan it follows the western coastline and its watershed is usually within 50 miles of the west coast. Due to tilting from west to east the western approach is more precipitous and difficult of access, and stream and river beds are deep-cut. Faulting has produced longitudinal rift valleys which constitute a discontinuous trough, extending a significant distance along the range. Volcanism has added to the complexity by laval outpourings of various ages and types, ranging from ash to andacite. 31 volcanoes are currently listed as active in Sumatra alone (Anon, 1957). Many outflows have spread east as sheets of pumice, tufa and ash, some in the original state and some as waterborne alluvials. In the Betak highlands in the north, for example, tufa from recent volcanism has obliterated all earlier relief over an area of some 14, 240 sq. kilometres. These outpourings have blocked parts of the median trough and caused re-direction of drainage and the creation of various lakes, some of which have subsequently drained away to leave alluvial basins. In the vicinity of Lake Toba acid volcanic rocks, in places 600 metres thick, have concealed the median trough and adjoining eastern Piedmont.

Basic material has been ejected from the now dormant volcanos in the north of the Betak lands and has given rise to fertile soils supporting tobacco. On the other hand, acid volcanic cinders deposited in some areas have covered the old surfaces with a mantle of porous acid material which supports only a shrubby savanna-like vegetation.

Erosion of the various volcanic mantles is often spectacular. Lake Toba situated inland from Medan at an altitude of 1000 metres is surrounded by a mountain wall up to 600 metres high and its outlet to the southeast plunges through tremendous gorges (Dobbie, 1965). Roads and tracks cut into the tufa and ash are heavily eroded on the slopes to stream and gully crossings. Around Lake Toba huge dormant cones occur, while to the south of the lake the in-filling of the median trough by tufa has resulted in drowned ranges on either side, only the higher peaks of which now emerge from a vast plain, flat except for deep erosion gullies. To the south of the Betak region the dormant Boeal Boeali volcano marks the beginning of the Barisan mountains proper and at this point the typical form of a trough formed by fault depressions between two ranges becomes well established. The eastern range is composed mainly of more resistant metamorphic rocks and, partly due

to the west to east tilt, slopes only moderately steeply to the coastal flats. The western range in contrast is made up of recently dormant cones and less resistant volcanic materials which have been heavily scored by erosion, especially on the steep western faces.

To the south of Padang the active volcano Gedoeng Kerintji (3805 m) is encountered and thereafter a number of other active cones occur southwards to the Sunda Strait. In the Barisian range granites, crystalline lavas and tufas are frequent. The median trough is discontinuously present.

Owing to the extent of coastal plains on the east coast half of the total area of Sumatra lies at an altitude of less than 30 metres.

6.32

Java

Java is a long, narrow island some 960 kilometres long and about 96 kilometres wide at the central waist, widening to 160 kilometres on either side of this. The island is largely contained by the parallels of 6° and 8° South latitude but, because it lies at a slight angle to them, the northwestern and southeastern tips of Java cross these latitudes.

Dobbie (1965) recognises five landscape types beginning from the south as follows:

1. The south coast limestone platforms
2. The median ridge and valley belt of disturbed sedimentary rocks
3. The line of volcanoes forming the axis of Java
4. A belt of alluvials from Bantam eastwards through the Loesi-Salo Valley to the Madoera Strait and enwrapping the volcanoes
5. The north coast limestone platforms of Rembang and Madoera

As the extensive plantations of *P. merkusii* are chiefly in the Bandoeng area which lies entirely within types 2 and 3, only these two are of importance in this context. The following brief descriptions are based on Dobbie (1965):

Type 2. The median range and valley belt is a maturely dissected landscape on marls which give rounded relief forms. Sedimentaries and limestones cover a third of the surface. The sedimentaries on the south

have derived from eroded volcanoes of previous geological eras and have been much folded and fractured. As in Sumatra, there tends to be a median trough among the ranges. Altitudes of over 1200 metres are reached by the sedimentaries which form a sub-structure of Java's highlands.

Type 3. The Javanese landscape is everywhere dominated by volcanoes which, with their lava and ash outpourings, mask the older landscape. Many cones are steep-sided and scarred by torrential rains. Dobbie (1965) notes that 44 cones are between 6000 and 10,000 feet high, while 14 are even higher and that, in few parts of the earth, are structural weaknesses and lava flows crowded together in such profusion. The Javanese volcanoes erupt more frequently with ash than with lava. The latter is generally basic and soils forming from the lava, or from alluvial ash derived from it, are generally rich in soluble plant foods and very productive. Owing to the abundant rainfall extinct cones have lakes within them, at least until erosion breaks down the rim. Percolating water may however set up steam pressure in some cones and cause explosions or the development of hot mud lakes, which may periodically overflow as lahars.

6.4

Soil

In his discussion of climate and soil in the Indonesian archipelago Mohr (1945), draws attention to the fact that the abundant rainfall not only wets the soil but most distinctly leaches it at the same time. This process is accelerated by the high uniform temperatures: at one metre deep the soil temperature at sea level remains constant throughout the year at a value between 25° and 26° C. The heavy downpours which characterise the rainfall pattern of the region also cause mechanical loss of soil through erosion, a loss which is accentuated in the mountainous areas due to the steepness of many of the slopes. This loss is especially serious as it involves the humus-rich top soil.

However, in Java in particular, but also along the mountain chain in Sumatra, the constant and continuing activity of volcanoes is a radical factor able to reverse the deleterious effects of leaching and erosion. The volcanoes concerned are the type which eject large quantities of ash, sand and stones over the surrounding countryside with resulting rejuvenation of the affected areas. Such new material may be expected to remain fertile for a very long period of time until leaching again takes its toll.

In respect of volcanic rejuvenation there is, however, an important distinction between Java and Sumatra. Not only are the volcanoes and volcanic activity more widespread in Java, but also the

ejecta of the Javanese volcanoes is basic in character and contains more calcium, magnesium, iron and phosphoric acid than the acidic ejecta of many Sumatran volcanoes which are relatively rich in silicic acid. In addition, potassium is usually found in more easily assimilable form in Java than in Sumatra. The better fertility and greater agricultural potential of the soil in Java explains the much denser population of that island as compared to Sumatra with its more acid ejecta and considerable areas of inaccessible lowland swamp outside the range of volcanism.

The soils of Sumatra have recently been mapped to a scale of 1 to 1,000,000 by the Directorate of Soil Science (Anon, 1964c).

Away from the wide coastal plains which comprise mainly organosols or humic gleis, alluvials and grey hydromorphic soils (Types 1, 2 and 3), the major soil groups in the uplands are a complex of red-yellow podsols/latosols/lithosols (Type 22), a complex of podsols/podsols/lithosols (Type 23), chocolate grey podsols (Type 19) and red-yellow podsols (Type 9). A total of 24 types have been recognised and mapped and these include regosols, andosols, latosols, rendzinas, brown forest soil and lithosols, as well as podsols and podsols.

A comparison of the soil map and the distribution map of P. merkusii in North Atjeh compiled by Brandts Buys, Japing and Fernandes (1928) shows that the extensive areas of pine occur predominantly on the red-yellow podsols developed on sedimentary material in wide upland valleys (Type 9), and on the upland soil complex comprising red-yellow podsols/latosols/lithosols (Type 22). Red-yellow podsols on intrusive parent material (Type 21), andosols (14) and latosols (15) both on volcanic parent material, and a complex of chocolate podsols/podsols/lithosols on escarpment sedimentary or metamorphic rocks are also found to carry natural pine but to a lesser extent. Most of the soil types bearing pine and particularly their red-yellow phases are likely to be acidic and relatively infertile.

On the basis of the soil types delineated on a schematic soil map of Indonesia prepared by the Soil Research Institute in 1967 to a scale of 1 to 5,000,000, it is probable that the majority of the plantings of Pinus merkusii in the Bandung region are located on andosols or grey-brown podsols.

6.5

Forest Types

The Indonesian flora is very rich in species; the number of tree species able to attain a diameter of 40 cms and over has been estimated

at about 3700, comprising some 450 genera (Anon, 1957). In Sumatra, complexity of land form, ranging from tidal flats and freshwater swamp, plains and foothills to mountain ranges and volcanic peaks, together with anthropic activity and the disruptive effect of volcanism, all contribute to a diversity of vegetation and forest types. Primary forests and secondary and derived vegetation of varying ecological status may all be found within a relatively small compass. In consequence a brief account of the forest types must necessarily be very generalised.

The predominant forest type in Sumatra is tropical rainforest, always green and humid and comprising several hundred species. The common species are, in the main, Dipterocarps. Economically important species are the red and white Meranti (Shorea), Keruing (Dipterocarpus spp.), Kapur (Dryobalanops), Damar Laut (Hopea) and Bangkrai (Shorea laveifolia). Eusideroxylon zwageri (Ironwood) - important due to resistance to Teredo - is scattered in small groups in South and Central Sumatra.

Tidal forests occur at several places along the coast. These mangrove forests produce large quantities of fuel wood and charcoal. Freshwater swamp forests produce mainly timbers with relatively soft wood such as Shorea and other Dipterocarps. Palaquium spp., Tetramerista glabra and Cratoxylon arborescens (Hayden-Guest et al., 1956). In North Sumatra extensive forests of P. merkusii are to be found on the mountain chain associated either with hardwoods or with extensive open grassy areas termed 'blangs'. There is a disjunct southerly extension of these forests to the vicinity of Mount Kerintji.

6. 6

P. merkusii in Sumatra

6. 61

Distribution and Extent of Forests

P. merkusii occurs in three disjunct populations in Sumatra. In all three the pine is found on the mountain chain which extends almost the full length of the Island. Details of the distribution are given by Buys et al (1928) in a comprehensive account of the pines in North Sumatra (Gajo-Landen).

The most northerly locality is the extreme north of the Island at about 1100 m elevation on the slopes of the Seulawaih Agam volcano to the northeast of Seulimeum. From this point southwards the pine is encountered along the mountains for some 300 kms, past Lake Tawar, Uwak and Blangkedjeren to about the level of Katajane. Occasional outliers of P. merkusii are found as low as 200 to 300 m above sea level but the majority of pine stands are at elevations between 800 and 2000 m.

This population represents the north Sumatran or Atjeh provenance.

A central population is located in the Tapanuli region to the south of Lake Toba. Junghuhn discovered the species in the mountains of Sipirok. He provisionally named it P. sumatrana. The herbarium material was sent to Governor Merkus who in turn passed it on to Professor de Vriese who published the first botanical description in 1845, naming the species P. merkusii Junghuhn et de Vriese in honour of the Governor who had died in the interim. Buys et al. mention several localities in the region from which P. merkusii has since been reported, mostly in small stands, groups or even as scattered trees. The most extensive occurrence, estimated at about 1200 to 1300 hectares in the 1920s, is associated with two mountains, Dolok Tusam and Dolok Pardumahan. Also in this region is the Dolok Saut Nature Reserve which contains some 40 hectares of P. merkusii associated with hardwood forest. Most of the reported occurrences occur at an altitude of 1000 to 1500 m between Pangarebuan about 50 km south of Lake Toba and Padangsimpuan another 50 kilometres further south. Mirov (1967) states that the area around Lake Toba (1000 m a. s. l.) was once covered to a large extent by natural stands of pine as is evidenced by scattered remnants and the place names.

A large break then occurs, no P. merkusii being known until the vicinity of Mount Kerintji 550 kilometres south of Lake Toba. Here the pine is found in several places surrounding the Kerintji Plain. The most northerly occurrence in this region lies some 15 kilometres to the south of Mount Kerintji. The most accessible area is that reported by Cordes in 1865 (Buys et al., 1928) on the road between Tapan and Sungai-Penuh. Lying a little more than 2° south of the Equator this is a unique record for Pinus in the southern hemisphere. The majority of these pine areas are reported to be at elevations between 1500 and 2000 m above sea level.

The Atjeh population is many times larger than the other two combined. In the 1930s it was estimated that some 115,000 hectares of pine existed in Atjeh. The area is now estimated at 200,000 hectares, partly due to the discovery of more pine stands, and partly due to the encroachment of pine into grassland and onto former hardwood sites. (Soedjarto, pers. comm., 1967).

In the Tapanuli region there are said to be 17,000 hectares of pine but this includes the large plantations in the vicinity of Lake Toba. No recent figures are available for the natural pine areas but these are probably to the order of 3500 hectares, on the basis of the area quoted by Buys et al. (1928).

The Kerintji population seems to be the smallest of the three. The numerous small stands and groups may total less than 3000 hectares in aggregate.

6.62

General Description of *P. merkusii* Forest (See Plates 7 and 8)

Flying over North Sumatra it is easy to discern even small groups of *P. merkusii* in the dense hardwood forest due to the light colour and the different textural appearance caused by the crown shape and thin foliage. The extensive stands of pine in certain blangs are also most conspicuous. Studying the pine distribution it is apparent that in effect two locations are involved. Firstly, there are small stands, groups or strips of pine set among dense hardwood forest (tropical rainforest) on the mountain slopes and, secondly, there is the pine associated with the extensive grassy clearings or blangs. In the latter location the pines may vary from isolated trees or small groups dotted about in the grass to extensive stands with canopy densities ranging from open or patchy to almost continuously closed. Another feature which strikes a stranger to the area is the number of scars discernible on the mountain sides often resembling the rock tips of mining operations but which are in fact landslides caused by frequent earthquakes and tremors in this region of active volcanism.

Inspection of the various sites on the ground reveals that the pine groups among the hardwoods are almost invariably to be found on relatively dry spurs or ridges or in long strips up and down the mountain-side. The pine crops on them are usually more or less even-aged, though they may vary considerably in age from strip to strip. In the younger crops it is usually possible to see clear evidence that the pines have in fact colonised the site of a landslide. This accounts for the linear shape of such groups. In the older crops the origin is not so easy to determine due to the invasion of the site by rank ground flora and by the regeneration of numerous hardwood species. Pine regeneration is however very rare or absent unless the soil is a poor volcanic tuff.

On the drier sites such as spurs, raised terraces, the upper zones of certain volcanic cones and on deep tuff, *P. merkusii* groups or stands of varying size occur. These are usually pure or nearly so and have a grassy or needle-strewn floor with good pine regeneration in gaps in the canopy and on any nearby exposures of mineral soil.

The extensive open grassy areas or blangs which are so typical of the mountain region in North and Central Sumatra require explanation. Buys et al. (1928) have discussed the origin of blangs at length. After considering and discarding the theories based on their possible survival as relics of a drier, semi-desert phase, they conclude that these open

spaces are the result of anthropic activity. They postulate that the early cultivators, either an invading people with a tradition of cultivation or indigenous hunters who turned to cultivation, gradually began to open up the primary forest by clearing and fire. In the mountain region, the sites chosen for settlement and cultivation would be on the banks of rivers which in the median trough (Section 6. 31) are often in wide and relatively flat valleys. These valleys traditionally serve as access routes between centres of population. Once cultivation commenced deliberate burning to keep the existing fields clean plus additional clearings would increase the destruction of primary forest around each settlement. Buys et al. point out that grass fires are also started to facilitate hunting and to provide new grass for cattle, so that the area cleared would be extended well beyond that actually needed for cultivation. They note that the ecotone between pine and hardwood forest is abrupt and not gradual, as would be the case if climatic rather than anthropic activity were the cause. Van Heurn (1923) is quoted by Buys et al. to the effect that blangs must be of anthropic origin in view of his observation of frequent relict patches of primary forest in ravines and other protected positions in their midst. Van Heurn himself mentions the role of fire in maintaining the blangs under grass but he goes on to say that 'the pines follow in the footsteps of the people and gain the upper hand where primary forest has been cleared, gardened and then abandoned.' In this Buys et al. feel that too much stress is being laid on the importance of actually gardening an area (Ladangen) since the practice of 'ladang' on the poorest soil where pines come in most readily, plays too insignificant a role to account for the great extent of many blangs. They repeat the view that while gardening may initiate a blang, the great extension of such areas is due to the constant eating away of the surrounding forest margin by fire. This aspect is considered further in section 6. 671, Fire.

My own observations are in agreement with those of Buys et al. except that I feel the importance of volcanism in permitting the pine to maintain a foothold in the midst of primary rainforest has not been sufficiently emphasised. The small pine groups which establish themselves as pioneers on volcanic cones and on mountain landslides function as centres of dispersion from which anthropic clearing in the valleys below may quickly be colonised. Indeed, as will be discussed later, landslips may even be of assistance in enabling pines to become established in certain blangs.

Secondly, the relative ease with which the hardwoods are eliminated over such very extensive areas is remarkable in comparison with mountain localities on the mainland of Southeast Asia. Despite a much more pronounced dry season in the majority of pine areas on the mainland, which would favour the destruction of hardwood forest by



Plate 7a. *P. merkusii* and *Imperata cylindrica* colonising unstable slopes of volcanic tuff near Lampahan, N. Sumatra. Note rainforest in valley and on the more stable slopes and ridges. Altitude, 1000 m. Rainfall about 1700 mm. Area subject to frequent earth tremors.

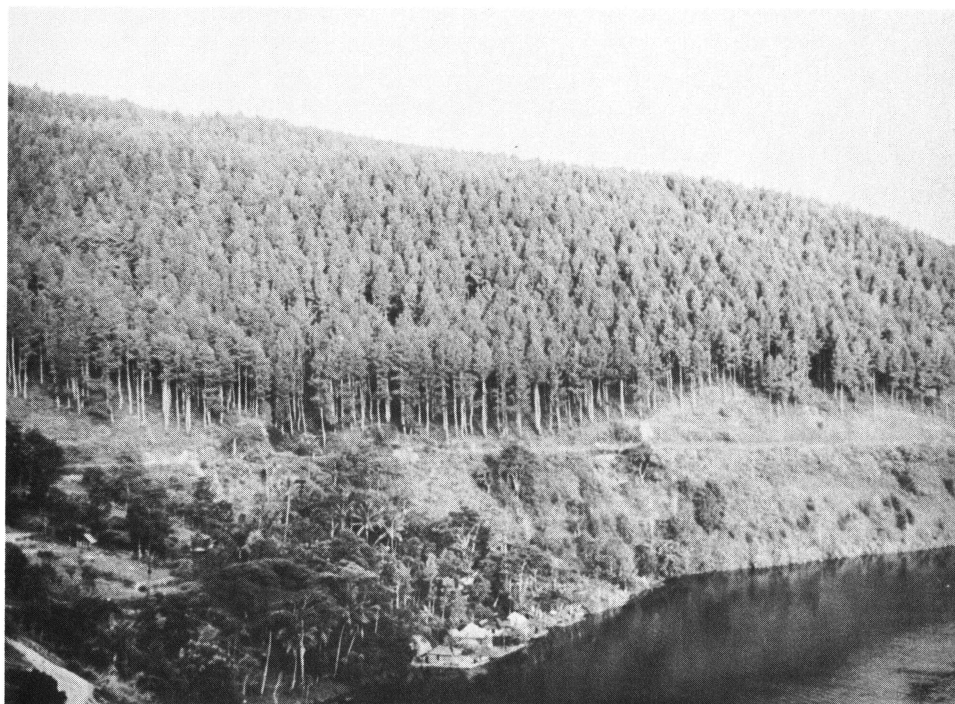


Plate 7b. Aek-na-Oeli Plantation, near Prapat, Lake Toba, N. Sumatra. *P. merkusii* mainly Atjeh provenance, planted 1937. Altitude, 1000 m. Rainfall, 1700 mm. Soil, liparitic tuff, poor and acid.



Plate 8a. *P. merkusii*, Tapanuli provenance, planted in small school plot in 1931, at Gultum village, near Pangaribuan south of Lake Toba, Sumatra. Av. d. b. h., 55 cms; height 40 m; altitude 1100 m. Stocking about 1000 stems per hectare. Rainfall approximately 2000 mm. Soil probably volcanic tuff, deep and acid.



Plate 8b. Typical light grey, thin, scaly bark of Tapanuli provenance. Photo taken in plot shown in Plate 8a. Pencil is 14 cm long.

fire, grassy clearings to the extent encountered in Sumatra are virtually unknown. Population density and land hunger do not seem to be the answer. In the mountains of Sumatra population density is usually under 20 per sq. kilometre (Dobbie, 1965). The answer almost certainly lies in the nature of the soil. It has been noted in Section 6.4 that the major pine distribution coincides with podsolic soils; further the ash and volcanic debris of the North Sumatran volcanoes is predominantly acidic and poor in nutrients. In their description of individual pine stands, especially those situated on blangs, Buys et al. frequently comment on the infertile and acid nature of the soil. Re-establishment of hardwoods, once they had been cleared from such sites would be relatively slow; even occasional fire would greatly favour the better adapted Imperata, Pteridium and Pinus merkusii to colonise and dominate such sites. It is noteworthy that in discussing the distribution of Pinus merkusii in the Kerintji region Buys et al. state that the most northerly occurrence of the pine in this area is some 15 kilometres to the south of the peak of Kerintji. 'The species is not encountered nearer to the peak; the volcanic soils there are very fertile so that the pine, if it ever was there, would have been ousted by hardwoods'. A further factor which may have a bearing is that the major pine areas in Sumatra coincide to a marked degree with the region of relative dryness shown on the map of rainfall types in Indonesia prepared by Schmidt and Ferguson (1951). Most of the pine areas lie within climatic Type B on this system whereas by far the greater part of Sumatra is in Type A. Although the difference between these types is not sufficient to cause a change in hardwood forests from evergreen to semi-evergreen or deciduous formations it may well be sufficient to place hardwood regeneration at a disadvantage in competition with Imperata, Pinus etc. on poor acid soils.

Short accounts of the individual P. merkusii forests visited in 1967 are given in Appendix II.

Growth Habits

Sumatran P. merkusii is a large, relatively fast-growing tree often rather sinuous or even spiraliform in youth but usually straight at maturity. Lasschuit (1941) commenced an investigation into this phenomenon in 1938 but it had to be abandoned 27 months later owing to the war. Results over this short period do not permit conclusions to be drawn with certainty but do provide interesting pointers. The spiral growth, for example, was found always to be left-handed. This refers to the spiral twisting of the leader in growth, and does not refer to 'spiral grain' in the wood.

6. 631

Size under Typical Conditions

Buys et al. illustrate (Photo No. 17) P. merkusii 70 m high in a group in a blang near Lampahan, and quote measurements by van Braam made in Gajoland in 1923 as follows:

Number of stems	29 (= 116 per hectare)
Average diameter	56 cms
Average height	60.6 m

At Radjavali near Lampahan I measured one specimen 49 m in height and 86 cms in diameter; this was not the largest tree in the area.

Trees of these dimensions are, however, rather exceptional and certainly very old.

Dimensions are a good deal smaller in the average secondary crop of the blangs but even there heights in the range of 40 to 50 m are fairly common and a large number are to be found over 25 m in height. Measurements made on 370 hectares in the Isaq valley (Buys et al., 1928) gave a total of 17,525 trees or 47 trees per hectare with an average diameter of 48.5 cms.

In Radjavali, near Lampahan, the same authors found the following timber volume on 11 hectares:

	No. of trees	Basal area in sq. m	Mean diam. cms	Timber volume cu. m
Total	1386	288.29	-	6,840
Average per ha	126	26.21	51	622

A form factor of 0.51 was derived from felled sample trees but a value of 0.50 was used for safety. Average tree height was found to be $47\frac{1}{2}$ m.

6. 632

Crown Shape and Branching

The Sumatra provenances of P. merkusii are characterised by rapid height growth and pronounced apical dominance in youth. There is positively no grass stage; on the contrary, seedlings are decidedly spindly in appearance.

Crowns are generally rather light and pyramidal or conical in youth, sometimes almost pointed-cylindrical. Branches become more spreading later but no marked rounding of the crown is noticeable until the trees reach considerable age and size.

In young trees branches are in distinct whorls; older trees have a more or less irregular branching habit.

The Atjeh and Tapanuli provenances are strongly multinodal. Counts of total branch whorls on random trees of known age in two different plantations in north Sumatra are given below:

Table 19

	Sari Plantation at km 69 Banda Atjeh/Bireuen Road (8 year old trees)	Puntjaling Plantation Tjiwideg, Java (10 year old trees)	Boer Ni Telong Plantation near Lampahan (10 year old trees)
	29	28	32
	19	30	33
	21	28	38
	23	31	39
	30	27	36
	27		
	149	144	178
Arithmetic mean	24.8	28.8	35.6
Average per year	3.1	2.9	3.6

(See also Section 6.66, Rate of Growth)

Bark

Buys et al. described the bark as follows ' The bark on the

leader is light brown; the bark on non-woody shoots is smooth and grey-green in colour; the bark on woody parts of young trees is smooth and grey-brown.

As the trees grow older the bark becomes grey/reddish-brown and scaly (Schilfers). Mature trees in mixture with hardwoods have grey/brown bark often scaly and then thin or partly scaly and partly in the form of plates, the platey part of the bark being thick. The lower portion of mature trees is grey/brown but the colour becomes reddish higher up the stem. With increasing age the plates become larger and the fissures between them deeper.

Based on measurement of numerous trees in pine stands Buys et al. give the following average size class data for bark thickness:

Diameter class of tree in cms	Bark thickness
16 - 20	2
24 - 30	3
30 - 40	5
39 - 50	5.5
48 - 60	6
67 - 80	6.5

One of the features differentiating the Tapanuli and Atjeh provenances is the bark (De Veer and Govers, 1952). According to these authors 'The bark of Tapanuli pines is mostly smooth, scarcely fissured, thin and light in colour. The bark of Atjeh pines is thick, dark coloured and heavily fissured already before the tree is 10 years old'. These differences appear to be genotypic because they persist in plantation grown trees. This aspect is discussed further in Section 7. 25.

6. 634

Root System

P. merkusii is undoubtedly firmly anchored by its root system or it could not survive as it does on steep unstable slopes and on exposed ridges.

The root system of a medium sized tree is illustrated in photo No. 25 in Buys et al. (1928) which shows a combination of good lateral development with deeper probing roots as well.

6. 635

Cones and Male Flowers

Cones when fully grown but green are almost cylindrical in shape with bluntly pointed ends. They occur singly, or in clusters of up to 17, though clusters of more than 7 mature cones are relatively infrequent. Ripe cones are found much further back from the branch tips than in the continental provenances. New female cones emerge at the tips of branchlets high in the crown and may be in dense clusters of twenty or more, but two to seven is more usual. The average length of cones is given by Buys et al. as 8 to 9 cms with 11 cms as the maximum. Length measurements on cones collected by me in 1967 from five random trees in Atjeh and in Tapanuli range respectively from 4.8 - 7.7 cms and 6.5 - 10.1 cms.

According to Buys et al., male catkins average 2.5 cms long; the period between their appearance and pollen shed is six weeks. Both male and female cones may occur on the same shoot during one season. Pollen shed has been observed by them at all times of the year but in Gajoland the main period is March - June. The main seedfall takes place between July and November. Poor seed years seem to occur from time to time.

6. 636

Seed

The seed is winged, the overall length being 25 mm and wing width 8 mm. The seed itself measures 7.5 mm long by 4.5 mm wide. Being somewhat flattened in cross-section it is ± 2 mm thick. 500 seeds weigh approximately 10 grams (Buys et al.). The 1000 seed weight determined in England on seed received from Blangkejerang, Atjeh, was 16.98 grams. (This is equivalent to 58,900 per kilogram or 26,800 per lb.) It is possible that the weight quoted by Buys et al. is for fresh seed at a relatively high moisture content. De Veer et al. (1954) record that 1 kilogram contains about 50,000 seeds without wings and that a kerosene can (18 litres) contains 800 to 1000 cones, yielding about 70 to 160 grams of seed. They state that collecting is most profitably done in the months of September to October after the dry period and that only cones which have just changed their colour from green to brown should be taken; these cones are ripe enough to yield fertile seeds. These ripening cones are 'oasted' on flat receptacles in the sun. The fertile seeds are sorted out when dry and stored in airtight containers.

Seed from the natural stands in Atjeh and also from the plantations in Java stands transport better than seed from the continent of Southeast Asia. Germination of 40 - 60 percent may be expected after transport overseas by air, provided the seed is fresh and has been air-dried before despatch. In Sumatra it is possible to keep the seed for

fully two seasons without special storage facilities provided it is sound and properly dried. (Buys et al., 1928)

A summary of the results of an investigation into the rate of seedling development conducted by Buys et al. is given below:

Period from germination	Length of Root	Length of Shoot	Remarks
8 days	1.5 cms	2 cms	Hypocotyl measured. Cotyledons still in seed coat
10 days	3 cms	2.5 cms	Light green in colour. Cotyledons mainly 8, sometimes 6 or 7. Seed coat still attached
14 days	4.5 cms	3 cms	Cotyledons expanded 3 cms long. 1 mm wide
21 days	6.5 cms	4 cms	Cotyledons 3 cms long
6 months	26 cms	15 cms	Cotyledons shed. Lower needles 10 cms. Upper needles 5 cms
8 months	35 cms	27 cms	Lower needles 11.5 cms. Upper needles 6.5 cms

6. 64

Regeneration

6. 641

Natural Regeneration

Although P. merkusii often colonises exposed mineral soil with conspicuous success the existence of bare soil is not a prerequisite for successful regeneration. This point is strongly emphasised by Buys et al. who disagree with an earlier opinion by Gonggrijp that mineral soil exposed by disturbance or fire was essential for satisfactory regeneration. While agreeing that such conditions may provide an excellent start for germination and seedling development, they point out that good establishment may be achieved under other conditions and cite an instance where a total of 3188 plants were counted in a quarter hectare plot among dense grass six feet tall on level but poor soil. Dense ground flora in itself is not a barrier to establishment as long as the seed can reach the soil. On the other hand matted vegetation, such as fallen fern and grass stems, thick needle litter, or a layer of undecomposed hardwood leaves may preclude regeneration.

The ability of P. merkusii seedlings to compete with grass, bracken and various shrubs and herbs under natural conditions was

noted by me on many occasions. Three typical examples are quoted:

- (i) Established regeneration of P. merkusii amongst moderately tall dense Imperata, Andropogon, Pteridium and various shrubs and herbs in a small opening 0.1 hectare in size bounded on one side by a metalled road and on the others by dense hardwood forest. This location was obviously less subject to fire than the open blang across the road where vegetation was less dense but pine regeneration very sparse.
- (ii) Good regeneration was found in gaps amongst dense rank ground vegetation on the edge of relict patches of hardwood forest on the approaches to Dolok Saut Nature Reserve. Ground flora comprised various grasses, bracken, Rhodomirtus, Erea japonica, Melastoma, Lycopodium, Nepenthes, etc. Again most regeneration was to be found in positions relatively protected from fire and not necessarily in the most open conditions.
- (iii) Excellent regeneration in groups under a generally rather open stand of pine managed for resin production in the Isaq Valley near Takingon. Here ground flora on certain slopes and aspects comprised tall, dense grasses amongst which regeneration was locally numerous.

Some patches of P. merkusii regeneration in North Atjeh are very dense indeed and much more reminiscent of P. kesiya seedlings in the mountains of Luzon than of continental P. merkusii.

On the question of the light requirements of P. merkusii seedlings, the species has the ability to grow satisfactorily in relatively small canopy openings and under conditions in which a good deal of side and some top shade is experienced. Undoubtedly this provenance of P. merkusii is to be found under denser canopy conditions than is usually the case with the mainland provenances. Nevertheless, it is correct to regard it basically as a 'light demanding' pioneer.

Under natural conditions in Sumatra fire, and not competition with ground vegetation, is probably the chief limitation to regeneration in blangs. The example of good establishment of pine along the line of a landslip near the crest of a ridge in an open blang (Appendix II, Section 1) may well have owed more to reduced fire hazard than to a reduction in competition from grass.

An interesting point in regard to natural regeneration is that there is no sign of mycorrhizal deficiency even in the seedlings colonising clearings or landslides a good distance from the nearest pine

stands. Even more surprising is the successful invasion of new volcanic detritus and ash sites, as on the upper slopes of volcanic cones such as Boer Ni Telong during periods of quiescence. This contrasts strongly with the experience in plantations as at Tjelimeta, Java, where 'mother plants' were necessary in seed beds within a plantation that had been in existence for many years. One wonders therefore if it is not perhaps more a question of the inhibition of favourable fungi on the richer less acid soils that may be employed in nurseries or selected for plantations rather than their absence from the region. Most natural sites are both acid and relatively infertile.

6. 642

Artificial Regeneration

P. merkusii has been extensively planted in Indonesia. In 1967 the total area in Java was said to be between 90,000 and 100,000 hectares made up of approximately 45,000 hectares West Java, 42,000 hectares Central Java and 15,000 hectares East Java.

The main planting in Sumatra has been done at Aek Na Oeli on Lake Toba where planting commenced in 1929. By 1940 a total of 5,300 ha. had been planted (Bottenburg and Govers, 1941). Some 15,000 hectares are now believed to be under plantation in the area and there is scope for considerably greater expansion.

Lowland planting on an experimental scale has also successfully been undertaken at Puntijaku near Palembang, Southern Sumatra. Ferguson (1949) concludes that the site index based on top height is more or less similar to that in upland plantations and he accordingly recommends further trials.

The techniques of artificially regenerating P. merkusii in Indonesia have been described by de Veer et al. (1954) in a paper to the Fourth World Forestry Congress. The following details are taken from this report:

6. 6421

Nursery Practice

Seed may be sown broadcast (50 grams per square m) in seed beds or in boxes. It is important to protect against insect damage. Seed and nursery beds are of the same pattern - one metre broad and 5 - 10 metres long, raised about 15 cms above the level of the paths which are 45 cms wide. The beds should be well drained because seedlings are very susceptible to damping off, mostly from Rhizoctonia solani, and occasionally also from Pythium and Fusarium spp. The soil should be light and the topsoil finely worked and smooth.

Seed beds should have plenty of sunlight; protection against excessive heat, 10 a.m. to 3 p.m., and against heavy rainfall if necessary. Movable shades about 1.2 m high and sloping to the west are advisable.

After sowing the beds are covered with a thin (3 mm) layer of fine earth or sand and a layer of dry pine needles or chopped up lalang or bracken as a precaution against the drying out of the topsoil.

Watering is necessary only when the weather is excessively dry and even then only once a day.

Germination begins within ten to twelve days, at which time the protective layer of dry needles is removed.

When the seedlings are 6 - 8 weeks old and have shed their seed coats they are dug up with a sliver of wood or bamboo and transplanted to the nursery beds. In these beds 'mother trees' are planted a year before at a spacing of 1 m. These mother trees, young trees from 30 to 80 cms in height, which already carry mycorrhiza on their root systems, are intended to inoculate the root systems of the new seedlings.

Seedlings are planted at a spacing of 10 x 10 cms around the mother trees. Inoculation occurs in a radiating fashion about each mother tree. After two years the beds are evenly inoculated and the mother trees are no longer required. It is stated that inoculation by means of already infected mother trees seems to be the only possible means of transferring the mycorrhiza to new P. merkusii seedlings. Trials involving soil from older pine stands or pure cultures of fungus have failed. Further, it is possible to make use of pine species other than P. merkusii as mother trees. Seedlings of Pinus merkusii have been successfully inoculated by mother trees of P. kesiya, P. massoniana and other Pinus species.

After transplanting from seed bed to nursery bed, which should preferably be done on cool moist days, the soil of the nursery beds between the seedlings should again be covered with dry needles or lalang to prevent drying out of the soil and weed growth. On dry days watering may be necessary but only once a day in the morning.

The extermination of damaging insects, such as crickets, mole crickets, grasshoppers, cutworm, ants, etc. is necessary.

Planting

Preparation of the field planting site depends on circumstances.

In thickly populated regions in Java most pine plantations are established by taungya plantations as in Burma. This method consists of forest plantations interplanted with food crops for the first one or two years and is at present said to create no silvicultural problems. It is claimed to be the easiest and least costly method of establishing a plantation.

In sparsely inhabited regions outside Java there are usually not enough people interested in taungya planting in remote areas. Preparation, planting and tending activities are therefore done by contractors on task work or by day labour. For both types of plantations the actual planting technique is the same.

After about eight months in the nursery beds the young trees are ready to be planted in the field. The best size is 20 to 25 cms. Only vigorously growing trees with one shoot are chosen. On removal from nursery beds the plants with their root system in a ball of earth are temporarily packed in fern leaves which are at hand and tightly bound up. Transport from the nursery to the field takes place in hampers carried by workmen. The use of roots enveloped in earth is considered safer than open rooted planting. The latter method has the advantage of lower transport costs but requires skilled, careful and fast workers and also cool, moist weather with no wind.

It is not necessary to prepare planting holes previously. The young trees are planted with their ball of soil in a hole quickly made at the time of planting. It is important however to ensure that tap roots are vertical in the hole and not bent or twisted. Planting is done at the beginning of the rainy season and preferably on cool, moist days.

6. 6423

Initial Planting Espacement

In different parts of Indonesia various planting espacements have been adopted. Initial planting space depends on the purpose of the pine plantation and on the local circumstances of labour and its cost.

When resin production is the main purpose initial planting space should be wider than if timber and veneer logs are the main object. When pulpwood is the aim initial spacing should be much tighter. Labour costs and also the availability of seed have an influence on the spacing selected.

In Atjeh where resin production is the main purpose plantations established by artificial means are wide-spaced from the beginning; 4 x 4 metres is the favoured initial spacing. There are two reasons for this: (i) scarcity of labour in the region and (ii) the indigenous pine

stands which served as a model are widely spaced by nature and fire.

In the Toba Highlands where re-afforestation was intended for hydrological reasons 3 x 3 m spacing has been used with the intention of obtaining a closed forest canopy quickly.

In plantations in Java and Bali where the taungya method is employed a 3 x 1 or 3 x 2 m spacing is preferred. Experience indicates that wide spacing should be applied only on the very best pine sites. On middle and lower quality sites it has been found that wide spacing makes choice more difficult when the first thinnings are due because poor stem form is more prevalent in these stands. On the poorest site the growth of the pine is not quick enough to suppressalang and fern growth within the four or five year period in which young plantations are most inflammable. In such cases it is better to employ narrower spacing, but narrower spacing imposes the need for early thinning. In some mountain regions Eupatorium pallescens has reduced the production in young pine stands, especially in those with wide spacing.

6. 65

Silvicultural Treatment

It is known that during the period of 1924 to 1933 cleaning and spacing operations were carried out in the natural P. merkusii forest near Lampahan in Northern Sumatra in order to encourage the development of even-aged second growth crops intended for resin production. It had been found that vigorous young trees gave a much higher yield of gum than the old trees in the original forest. Apart from this, and the encouragement of regeneration in the natural forest around Lake Tawar by rigid fire control, no silvicultural operations in natural forest are known.

In plantations, particularly in Java, two or three weedings are considered necessary in the first year and one or two in each subsequent year until the canopy closes. The first thinning is usually carried out between the ninth and tenth years and thereafter approximately at 5-year intervals. The desired degree of thinning is expressed as an espacement of stems equal to about 22 percent of the top height of the stand. This is known as the S%, the 'relative space', given by the formula:

$$S = 100 S_m / O_h$$

in which O_h is the top height of the stand and S_m is the main (? average) distance of the trees considered in triangular position.

S_m is computed from the number of trees per hectare (N) :

$$S_m = 107.5 / \sqrt{N}$$

The intention is that whenever the S value of a stand decreases to about 20 percent a thinning is performed which results in an S value of about 25% (Ferguson, 1954).

6. 66

Rate of Growth

In order to obtain information on the rate of height growth in natural regeneration Buys et al. (1928) established two 100 plant sample plots. One near Lampahan was situated on a flat terrain on shallow unproductive soil on volcanic ejecta from the Boer Ni Telong, the second was on the Gajo Road near kilometre 84 on a similar site. Both were considered to represent the poorest possible site qualities. The results were as follows:

<u>Plot 1</u>		<u>Plot 2</u>	
Average ht. on 24. 7. 25	26. 1 cms	Average ht. on 15. 5. 25	124. 6 cms
Average ht. on 24. 7. 26	86. 9 cms	Average ht. on 15. 5. 26	232. 9 cms
Average ht. increment in one year	60. 8 cms	Average ht. increment in one year	108. 3 cms

On the assumption that the plants on site 1 were about 8 months old on 24. 7. 25, having derived from the October seedfall, and that the plants in the second plot were about 32 months old on 15. 5. 25 they conclude that even on poor sites a plant $3\frac{1}{2}$ years old would be about $2\frac{1}{2}$ m high.

Counts of branch whorls were also made on the plants in Plot 2. These showed an average of 2 whorls per plant at 15. 5. 25, 4 whorls per plant on 15. 11. 25 and 6 whorls per plant on 15. 5. 26, thus confirming the multinodal habit of this provenance. (See section 6. 632) Foxtail growth is also encountered in the natural crop: Boys et al. found an internode of 5. 53 m in length immediately below a 'crow's nest' of terminal branchlets. The internode itself had arisen from a whorl containing an excessive number of branches (photo No. 40 Buys et al., 1928).

Diameter growth in young natural regeneration was determined on 86 trees in a sample plot with a mean diameter of 26. 7 cms. These were found to have increased to an average of 28. 7 cms one year later. Interim measurements indicated that the bulk of the increment occurred during the westerly monsoon (wet period).

The same authors also attempted to relate growth rings to number of internodes but with inconclusive results. They state that

growth rings are very indistinct. An attempt was made during my visit in 1967 to correlate growth rings in plantation grown trees of known age at Boer Ni Telong plantation near Lampahan and in Puntjaling plantation in Java. Ocular estimation of growth rings was virtually impossible and no correlation with known age was obtained. Similar difficulty was encountered in young and mature natural trees (see Section 7.4 Growth Rings).

The following information on growth and yield is based on the paper by de Veer et al. (1954).

Investigation into the growth yield of P. merkusii was started by means of sample plots established in the first plantation of the species in Java. At the end of 1952 data were available from a sufficient number of plots to merit the construction of a provisional yield table (Ferguson, 1954). Since these tables were to be used as a basis of planning by the Forest Service they were extended by extrapolation to an age of 35 years. The data from age 30 years onwards must therefore be used with caution. Table 20 is an extract from the growth and yield table as published by Ferguson:

(Notes on Table 20) In Indonesia, contrary to general use, the best site quality is indicated by the highest number. Site class 1 therefore indicates the lowest site quality. The quality class is estimated from the top height, i. e. the average of the hundred highest trees per hectare equally scattered over the stand. This is about the same as the average height of the hundred most dominating trees per hectare. The volumes given in the table refer to the timber volume under bark to an over bark diameter of 7 cms. The volumes are valid for normal stands with sound boles. Deductions for lower stand density, for defects in the bole, and eventually also for a lower rate of merchantability, will be provided for later. The Forest Service has fixed the rotation provisionally at 30 years. This is somewhat more than the age at which the average annual increment culminates, being 25 years and lower at medium size classes and 20 years for better sites. It is to be expected that the produce of these forests will eventually be used as pulpwood. Since many of the forests have a function for the control of erosion and water supply in stream basins the rotation should not be too short and in this connection thirty years seems to be adequate.

A stand table for P. merkusii has also been prepared (Hutadjulu, 1961), and forms a supplement to the yield table. It was constructed by the graphical alignment chart technique, using data from 222 plots which Hutadjulu considers insufficient for more than a preliminary table. The data in the table refer to the main stand only. Two graphs are provided to give information on diameter frequency distribution and the location of average diameter (by basal area).

Table 20

Site quality class	Upper height (m)			Number of trees per ha. main stand			Average diameter (cm)			Total basal area (m ² /ha) main stand		
	age			age			age			age		
	10	20	30	10	20	30	10	20	30	10	20	30
	10.2	21.0	28.0	945	417	236	12.6	28.6	38.9	11.8	26.9	28.1
II	10.2	21.0	28.0	945	417	236	12.6	28.6	38.9	11.8	26.9	28.1
IV	14.7	27.0	34.6	857	253	154	19.3	37.5	48.7	25.1	27.9	28.7
VI	19.6	33.0	41.2	481	170	109	26.5	46.3	58.5	26.6	28.6	29.2

cont.

Site quality class	Volume main stand (m 3/ha)			Total production (m 3/ha)			Average annual increment (m 3/ha)		
	age			age			age		
	10	20	30	10	20	30	10	20	30
	37	178	248	37	289	471	3.7	14.4	15.7
II	37	178	248	37	289	471	3.7	14.4	15.7
IV	115	238	322	125	445	643	12.5	22.2	21.4
VI	164	303	397	253	601	814	25.3	30.0	27.1

Pinus merkusii has also been used in Indonesia for experimental plantation on lowland plains. One such plantation is situated in Puntikaju, near Palembang, South Sumatra and the other is the experimental centre at Tjikampek, West Java. On the basis of measurements in these crops in 1949 Ferguson concludes that the site index based on the top height is not on the whole inferior to that of mountain stands of the same species. Diameter increment in Tjikampek is similar to that at higher altitudes but at Puntikaju it is rather less. The inferiority at the latter station may be due to fire and some damage caused during the war. Although P. merkusii grown in the lowlands is said to be more crooked and more heavily branched Ferguson states that this cannot be established from these experiments. He concludes that the results are encouraging and recommends further trials on a larger scale. In contrast, Buys et al. reported that the low altitude natural stands of P. merkusii in North Sumatra failed to attain the large dimensions of the higher altitude trees and also that their crowns became flattened much earlier and the cones were unusually small.

6. 67 Injuries and Protection

6. 671 Fire

While fire has been shown to be one of the main agents ensuring the spread of pine onto sites previously occupied by hardwoods or facilitating regeneration under certain conditions, it is also one of the major threats to the continued existence of natural stands and plantations.

Besides destroying much of the young regeneration less than two to three metres in height (probably four to five years old) the passage of grass fires causes damage to older trees despite their thick bark. This may be due to fire gaining a hold on basal scars caused by villagers cutting resinous wood for kindling and torches or other forms of damage. Quite frequently sound trees are damaged as a result of fallen branches or trunks lodging against them and burning. Fire is then concentrated sufficiently long in one spot to eat through even the thick bark of the Atjeh provenance.

As one would expect de Veers and Govers (1953) state that the thin-barked Tapanuli provenance is more susceptible to fire damage than the thick-barked Atjeh trees.

On steep slopes fire is more damaging to tree crops than on ridge tops or flat terrain. This is because there is a tendency for flames in the tangle of vegetation in the drier lower branches of trees higher up the slopes to cause damage to the upper crown of those lower

down on the slope (Buys et al.). They observed that damage to crowns is rare on ridge tops and flat terrain, but relatively frequent on steep slopes.

The danger of uncontrolled fire in forest being worked for resin production is especially great. Tappers commonly clear a small circle round the base of each tree to minimize the risk of the resinous wood at the base catching fire.

Buys et al. proposed in 1928 that management of natural forest should include provision for controlled burning in as much of the forest as possible with complete protection in current tapping areas and in the regeneration blocks after a thorough burn in the latter to clear vegetation prior to seedfall.

Fire is a constant threat to pine plantations especially those in the Lake Toba region which is wet enough for rank undergrowth in younger stands and an accumulation of branches and litter in the older ones, but is at the same time subject to up to two months of dry period annually.

6. 672

Shifting Cultivation

Clearing of hardwood forests for shifting or semi-permanent cultivation is certainly one of the factors responsible for the spread of pine in Sumatra, but, to a greater degree than on the mainland, other factors such as volcanism and the great extension of initial garden clearings by fire are involved as well.

6. 673

Grazing

In the blangs of North Sumatra and in the Tapanuli area grazing is an important factor in the success or otherwise of pine regeneration near centres of population. In general grazing with consequent compacting of soil and trampling of plants is harmful on flat ground but may not be so serious on steep slopes since the animals tend to follow well-defined paths. Buffalo and horses are both known to browse P. merkusii shoots to a slight extent (Buys et al., 1928). However, the chief disadvantage of grazing is that the cattle owners are likely to ensure thorough annual burning to encourage grass for their stock, thus greatly limiting the chances of successful regeneration.

6. 674

Wind

Wind damage in the natural stands seems to be very rare. I saw no evidence of it during my visit despite the exposed ridge-top position

of many groups and stands. Sumatra does not lie in the path of typhoons from the South China Seas but disturbances on the inter-tropical front can sometimes result in violent winds. Volcanic activity can also cause major air turbulence. Some wind damage was observed in the plantations on slopes above Lake Toba but inadequate thinning could have been a contributory factor, especially in view of the likely prevalence of scarp face winds. Some stems had also been weakened by stem-boring Pyralidae.

6. 675

Insect Pests

A looper caterpillar Milionia basalis Walk. (Geometridae) is a serious pest of P. merkusii in Indonesia. A heavy attack on plantations in the Karo highlands occurred in July - August 1926 (Buys et al., 1928) causing almost complete defoliation. Control was achieved by spraying with lead arsenate. Local inhabitants did not recall a similar attack on natural pines.

In 1951 10,000 acres of pine plantation at Aek Na Oeli, Lake Toba, were completely defoliated (de Veer and Govers, 1952). By January 1952 the majority but not all trees had recovered. Investigations revealed that stands and individuals of Tapanuli provenance had nearly all been killed or fatally weakened by the attack. In contrast recovery was good in trees of Atjeh provenance (de Veer and Govers, 1952). This differential effect could be seen in an experimental hectare of Tapanuli trees completely surrounded by plantations of Atjeh type of the same age, and also in stands planted with the two provenances in mixture, although superimposed fungus damage complicated the latter comparison.

Damage to garden trees of P. merkusii in its natural range at Takingon near Lake Tawar by a small bagworm of the genus Psychidae was reported in 1927 (?) by Buys et al. These insects had caused severe browning of crowns due to damaged needles. The same genus has also been reported from the Aek Na Oeli plantations (Bottenburg and Govers, 1941) but does not seem to have developed into a major pest.

A shoot and stem boring pyralid causes severe malformation of Atjeh trees in Aek na Oeli and Toba highlands plantations. De. Veer and Govers, (1952) are of the opinion that defoliation by Milionia may have been a predisposing factor.

In the view of Mangunibikoro and Depari (1958) chemical control of Milionia, the Pyralid and also of a leaf wasp of the family Tenthredinidae is not feasible in North Sumatra plantations. They consider that biological control merits further investigation but that plantations on

liparitic soils (as at Aek Na Oeli) ought to be mixed with deciduous tree species to avoid pests and diseases, or that plantations should be established on the better soil of primary forest sites. De Veer and Govers (1952) report that a termite attacking the roots of P. merkusii has been identified as Coptotermes spp.

Seed and seedlings are very prone to attack by a variety of insects including ants, crickets, mole crickets, grasshoppers, cutworms and various ants. Losses from some of these occur both in natural and artificial crops.

6. 676

Fungi

Armillaria spp. is reported to have caused root rot of pines at Aek Na Oeli (de Veer et al. , 1954) but this fungus might not have become a serious danger but for the weakened state of the trees following defoliation by Milionia (de Veer and Govers, 1952).

N. B. As far as could be ascertained the plantations in Java are relatively free from insect and fungus damage.

6. 677

Animals

There is little recorded damage by the larger wild animals in natural forest except deer which occasionally eat young shoots. However mice and birds are considered to consume significant quantities of seed in the forest and may become troublesome in nurseries as well, (Buys et al. , 1928).

6. 68

Wood Properties and Uses

According to de Veer et al. (1954) the sapwood is white, the heartwood light reddish brown in colour without growth rings. Absolute specific gravity is 0. 50 (maximum 0. 59, minimum 0. 42). Fibre length is 2 - 6 mms with an average of 4 mms.

Density determinations on cores collected in June 1967 in Puntjaling plantation, Java; in planted trees at Boer Ni Telong, Sumatra and in natural forest at Dolok Saut, Tapanuli, gave the following results expressed on the basis of saturated volume and ovendry weight:

- | | | |
|--------------------------------|---------------------------------|--------|
| 1. Buer Ni Telong, Sumatra | 7 year old trees average of 5: | 0. 429 |
| 2. Puntjaling Plantation, Java | 10 year old trees average of 5: | 0. 395 |
| 3. Tapanuli, Sumatra | 1 young tree: | 0. 378 |
| 4. Tapanuli, Sumatra | 1 mature tree: | 0. 433 |

In North Sumatra the local inhabitants distinguish between two types of P. merkusii, one termed bunga (flower) and the other batu (stone). Hardness and weight are two among several differences claimed to differentiate these two types (See section 7.4). The following values were obtained on single samples of each type collected at Lampahan near North Sumatra. Comparable data for one specimen of Tapanuli provenance P. merkusii is included. These values must be treated with extreme caution as they may not be representative. Proper sampling procedures could not be followed:

Type	Density	Fibre Length Average of 50 fibres
Bunga	0.565	4.85 mm
Batu	0.650	5.78 mm
Tapanuli	0.436	3.04 mm

Ring counts were attempted on a total of 13 fresh increment cores in the field but no useful conclusions could be drawn due to extreme uncertainty as to ring boundaries.

The same cores were re-examined at Oxford in an airdry state with one sanded face to facilitate recognition of boundaries. Counts made on five trees from a ten year old compartment in Puntjaling Plantation, Java were: 9, 26, 8, 21, 13. Counts on cores from seven-year old trees at Boer Ni Telong were: 13, 20, 20, 30, 23.

Cores from 3 natural forest trees near Dolok Saut were similarly examined and found impossible to count with certainty. One, for example, was thought to have 39 reasonably clear rings and 20 false or dubious rings. Growth rings may thus be considered indistinct and unreliable as an indication of age.

In North Sumatra, P. merkusii timber is used in house construction and has been exported (to Japan among other countries) as peeler logs and for pulpwood.

Plantations are expected to provide pulpwood and timber for building purposes and veneer (de Veer et al., 1954).

when trials were established on the slopes of Boer Ni Panti. The trials were extended in 1924 to Lampahan where various techniques of tapping were tried in natural forest in the vicinity of Boer Ni Telong. Buys et al. (1928) have given a very comprehensive account of these trials as well as details of the chemical and physical properties of the resin and turpentine obtained.

The initial experiments were continued for the next nine years and were expanded to include various methods of managing the forests to increase the number of young, vigorously growing trees.

Moon (1945) reports that by 1933 sufficient data had been obtained to warrant the starting of a small commercial enterprise which in its first year yielded 600 tons of rosin and turpentine. During the next 4 years progress was such that a central distillation plant was built at Lampahan in 1937. This plant had a capacity of 40,000 tons annually of combined rosin and turpentine and was designed for easy expansion. The gum was collected at various points in the forest area and delivered to the distillation plant in tank trucks or drums over an average haul of 50 miles or more. The finished product was transported by truck a distance of 140 kms to the port at Lok Seumawe, the rosin being packed in boxes of 100 kilograms and the turpentine in drums of 200 litres each. Towards the end of 1941 the output had been brought up to 12,000 metric tons, 75% as grade X rosin and 25% as turpentine. At that time the net forest area under development was 113,000 hectares which was conservatively expected to give a yield of 750 kilograms per hectare of rosin and turpentine, equivalent to a total of 90,000 tons per annum.

The Lampahan factory is still in operation although tapping is now believed to be confined to a smaller area on a rotational basis. The 1966 production was said to have been 2,223 tons of rosin and 513 tons of turpentine. The crude oleoresin was stated to yield 65% rosin, 15% turpentine and 20% waste products.

6.70

Seed Availability

A seed collecting team provided with four-wheel drive vehicles and tree-climbing equipment should be able to obtain very large quantities of seed in the forest on the blangs of North Sumatra. In view of the reported occurrence of good and poor seed years and the erratic ripening of cones over a long period a preliminary survey would be necessary. The plantation at Lake Toba and also in Java themselves offer opportunity for the collection of mainly Atjeh provenance seed. In this connection it must be borne in mind that the annual planting target in Indonesia is 20 to 30,000 hectares of P. merkusii so that local seed requirements amount to some 3000 kilograms of seed per annum.

Regarding possible threats to the survival of the three recognised provenances of Sumatran P. merkusii there is no danger to the Atjeh race. In Sumatra the natural stands are probably still extending their range, while the plantations in Java and Sumatra are almost exclusively formed from Atjeh seed.

The position of the Tapanuli population is less secure. Its area is relatively small and the clearing of pine stands for cultivation is in progress. This race is not at present used in planting schemes owing to the difficulty of access to the natural stands and partly because it has been found to be very susceptible to damage by Milionia when used in plantations near Lake Toba. A small area of some 40 hectares in extent at Dolok Saut has been declared a Nature Reserve but since the pine there is mixed with relatively dense secondary hardwood forest its long-term future may not be secure.

The Kerintji population was not visited but as it is the smallest of the three and it is reported to occur in dispersed groups and small stands in good quality broad-leaved forest, it is possibly the most vulnerable. In view of the important role of this pine in forestry projects in Indonesia and its potential value to other tropical regions it is felt that a survey of the Tapanuli and Kerintji populations is required to determine their extent and status as a basis for the conservation of representative areas. It would be desirable to include the Atjeh populations in such a scheme as well despite their relative abundance. The differences reported between the Tapanuli and Atjeh provenances as regards stem form, bark characteristics and susceptibility to disease lend weight to these proposals.

7.0

VARIATION IN P. MERKUSII

7.1

Review of Literature

P. tonkinensis Chev. has been distinguished from P. merkusii by Chevalier on the basis of needle length, cone size and glossy apophyses (Chevalier, 1944), and also by certain anatomical differences (Greguss, 1955, quoted by Nguyen Kha, 1967).

Apart from this no formal taxonomic descriptions of varieties or sub-species appear to have been made. An anonymous author in Bois et Forêts des Tropiques, 64: 1957, distinguished several races having different ecological needs but noted that the limits of each race were still not precisely known. The various races were identified and described as:

1. The Plains Race: Examples occur in Siam and Cambodia at altitudes between 50 and 150 m in the valley of the Mekong and its tributaries. Rainfall averages 1000 to 1800 mm with a dry season of four to six months. This race invades gaps in the closed semi-deciduous and closed dry forest and forms mixed stands with broad-leaved species. It seems to prefer well-drained alluvial soils but will grow on poor soils such as loose sand or kaolinitic clays.

2. Upland Races: Two types can be distinguished clearly (a) the race of the plateaux and foothills of Vietnam, Laos, Cambodia, Thailand and Burma which invades poor granitic sands at altitudes of 400 to 900 m and a rainfall of 1500 to 2000 mm with a dry season of two to four months; (b) a race of the mountains of Sumatra occurring at an altitude of 500 to 1500 m (possibly extending from 60 to 2000 m) with a humid climate, rainfall 1500 to 2500 mm and a dry season of two to four months; it occurs on well-drained soils. This race divides itself into two forms:

- (i) Smooth bark
- (ii) Rough bark

but the ecological requirements of these two are still not clearly defined.

In contrast Mirov (1967) has described P. merkusii as 'not a very variable pine', noting that it is easily recognised throughout its discontinuous range by its two needles and narrow cylindrical cones.

Bottenburg and Govers (1941) point to the practical value and potential significance in a breeding programme of the distinction locally made between the 'bunga' and 'batu' types of P. merkusii both in Atjeh

and North Tapanuli, even if such distinction is not taxonomically valid. The former type is found to yield much larger quantities of resin than the latter.

This particular distinction is applicable to both the Atjeh and Tapanuli populations and appears to cut across the later discovery, reported by de Veer and Govers (1952), of remarkable differences between the Atjeh and Tapanuli populations of P. merkusii which may be summarised as follows:

<u>Character</u>	<u>Atjeh</u>	<u>Tapanuli</u>
Stems	Usually corkscrewed in youth	Straight and slender
Foliage	Thin and grey-green	Dark green and glossy
Branches	Branches on older trees heavier and more horizontal	Branches on older trees more slender and forming smaller angle with the stem
Internodes	Shorter and less regularly spaced	Relatively long and regularly spaced
Bark	Thick, dark coloured and heavily fissured before the tree is 10 years old	Mostly smooth, scarcely fissured, thin and light in colour
Susceptibility to <u>Milionia basalis</u> Walk. (Geometridae) attack	Recovers well	Killed or seriously weakened

7.2 Morphology

7.21 Seed

Considerable variation in seed dimensions occurs among the various provenances of this species. The results of standard 1000 seed weight determinations made by the Seeds Section, Forestry Commission Research Station, Alice Holt, England on seed collected by or supplied to me are given in the following table:

Table 21

<u>1000 Seed Weight, by Provenances</u>				
Origin	Ident. No.	Altitude in metres	1000 pure seed weight in gms.	No. of seeds per kilo
Thailand				
Srisaket	66(593)	130 m	24.6)	
Thailand			)	
Srisaket	66(593)2c	130 m	23.9) Av. 24.7	40,600
Thailand			)	
Srisaket	67(593)	130 m	25.7)	
Thailand				
Baw Luang	66(593)113	900 m	35.8)	
Thailand			) Av. 35.5	28,200
Baw Luang	66(593)117	900 m	35.2)	
Cambodia				
Kirirom	67(596)1	750 m	30.7)	
Cambodia			) Av. 31.5	31,700
Kirirom	67(596)2	750 m	32.4)	
Cambodia				
Pursat	67(596)4	20 m	23.7	42,200
Philippines				
Santa Cruz,				
Zambales	65(914)	200 m	24.3	41,100
Sumatra				
Blangkejerang	67(921)1	900 m	17.0	58,800
Java				
Randudongkal				
Plantation(seed				
originally from				
Sumatra)	67(922)	800 m	17.2	58,100

Other data regarding seed weight and the authority concerned are given below:

Table 22

Seed Weight by Provenances (from literature)

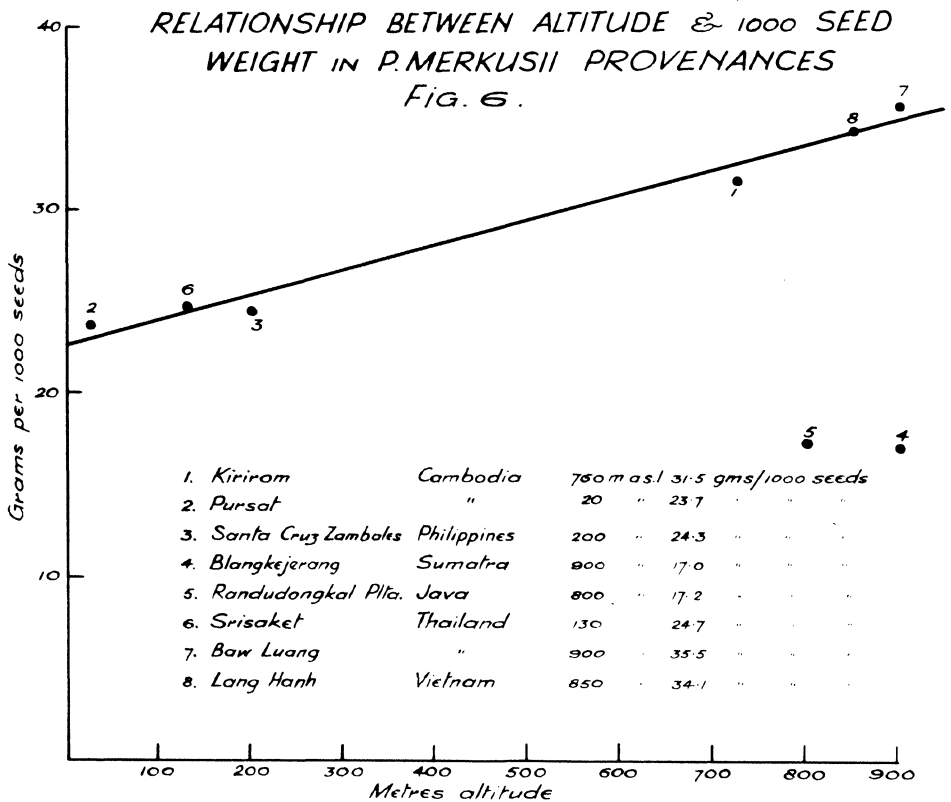
Origin	Altitude	1000 seed wt. (gms.)	No. of seeds per kilo	Authority
Sumatra, Atjeh	± 1000 m	20 approx	50,000*	Buys et al., 1928
Vietnam	800-900 m	34.1	29,320*	Nguyen Kha, 1966
Indonesia	?	20 *	50,000	de Veer et al., 1954
"According to variety"	?	37.0 *	27,000)	Anon, 1959
	?	16.7 *	60,000)	
Burma	?	23.8 *	42,000*	Troup, 1921

* Converted from the units given by original authority.

Although important information concerning origin is missing for some of the entries in the second table it is apparent that the two sets of data are not inconsistent.

Seed weight plotted against altitude (Fig. 6) shows good correlation between increasing altitude and increased seed weight for the mainland and Philippine provenances. On the other hand the Blangkej-erang, Sumatra seed, although from high altitude (900 m), is about half the weight of mainland seed from the same altitude. This difference does not seem to be explained by the difference in latitude as may be seen from the details given overleaf:

It is therefore concluded that the Sumatran populations as sampled do not conform to the pattern of the mainland and Philippine provenances.



7. 22

Seedling Characteristics

The mainland provenances of P. merkusii from Burma, Thailand, Cambodia, Vietnam and Laos are characterised by a grass-stage in the seedlings. In contrast the seedlings of Sumatran P. merkusii do not show any sign of a grass-stage at all.

Seedlings of the Philippine Island provenances from the coast of Zambales, Luzon and from Mindoro Island are believed to have a grass-stage but natural regeneration in these forests is very sparse as a consequence of frequent fire and the material available for study is inadequate.

Typically, grass-stage seedlings make very little height growth for the first three to five years. Instead most meristematic activity is concentrated on the production of what appears to be secondary cortex and tightly packed long, stout, secondary needles. In appearance, therefore, the seedling resembles a dense tuft of grass in which is concealed a short thick stem, the height : diameter ratio of which is commonly in the range of 1 : 10.

Seedlings of Sumatran origin on the other hand exhibit pronounced apical dominance and put on considerable height growth in relation to diameter, the ratio being to the order of 1 : 50. Shoot elongation is such

that the primary needles are relatively widely spaced on the stem. In grass-stage seedlings the needles are crowded into a very dense terminal tuft. The rate of shoot elongation in the Sumatran provenances is maintained or increased when secondary needles form. Although these have a tufted appearance on branchlets when the latter develop, the main stem or seedling axis is readily seen through the spaced covering of needles. In contrast, the short thick stem of the mainland provenances is totally obscured by the needles.

Plate 9 illustrates typical *P. merkusii* seedlings with and without a grass-stage and collected respectively in Vietnam and Sumatra. The proportion of the seedling stem radius occupied by secondary cortex in grass-stage seedlings is usually greater than that occupied by wood. In non grass-stage seedlings the cortex and secondary cortex together account for only a fraction of the radius, most of which is woody. Measurements on the cross sections of representative natural seedlings estimated at two to three years of age show that, in grass-stage seedlings the radial width of bark is usually equal to up to twice that of the wood, whereas in seedlings without a grass-stage the bark represents only about 5 percent of the radius, the remainder being wood. Plate 9 illustrates representative seedlings from seed imported from Vietnam and from seed collected in a trial plot in Zambia grown from seed of Indonesian origin. The seedlings shown were grown under identical conditions in a nursery in Zambia. Note that despite growth in a very seasonal climate (six months rain; six months dry) the Indonesian (Sumatran) seedlings have not developed a grass-stage, although one generation in Zambia would have presented the opportunity for some local adaptation.

Dr. R. G. Pawsey, Commonwealth Forestry Institute, Oxford, has kindly made microscopic examinations of cross sections of the following seedlings:

1. Natural Seedlings

- (a) Grass-stage. Vietnam, Lang Hanh area; Cambodia, Kirirom Plateau and Srakanome.
- (b) Non-grass-stage. Sumatra, Kalisampe Camp, Atjeh.

2. Seedlings grown in Chati Nursery, Zambia

- (a) Grass-stage. Raised from seed imported from Vietnam
- (b) Non-grass-stage. Raised from seed collected in a trial plot in Zambia grown from seed imported from Indonesia.

He reports as follows:

"The most striking differences between the basal seedling stem structure of 'normal' and grass-stage plants, apart from the much more extensive development of xylem, are: (a) the extent and nature of the parenchymatous region outside the conducting phloem tissue and (b) the development of cork tissue.

In the 'normal' seedling stem (Plate 10b) the parenchymatous region outside the phloem is true primary cortex comparable in radial thickness with the phloem. The cortical cells contain numerous starch grains and there is no evidence of medullary structures. A single peripheral cork cambium is formed which gives rise to a narrow phellem or cork layer.

In the grass-stage stem (Plate 10a) there is a thick basically parenchymatous region outside the phloem which consists of two zones: (a) an outer region of primary cortical origin and (b) an inner region, usually more extensive radially than the outer zone, through which medullary structures continuous with the rays passing through the phloem occur. These structures, together with less distinct evidence of radial orientation of some cells in the non-medullary tissue in this region, strongly suggest a secondary origin and for convenience this tissue is termed here 'secondary cortex'. The cells of the secondary cortex contain numerous starch grains, and cells apparently filled with resin or gum are of frequent occurrence.

In addition to a continuous peripheral cork layer in the grass-stage stem, internal cork cambia are formed in the true cortex and also in the outer region of the 'secondary cortex'. These internal cork cambia form an irregular lattice (in transverse section) of narrow layers of cork cells that apparently become suberised.

Plates 11a and b are of transverse sections through the stems of nursery-sown seedlings of 'normal' and grass stage plants respectively, both cut at about one inch above ground level. Comparable sections of natural seedlings of normal plants (Kalisampe Camp, Sumatra (ENC393) and grass-stage plants (Lang Hanh, Vietnam (ENC358); Kirirom (ENC348) and Srakanome, Cambodia (ENC356) were also examined and the differences described above between nursery raised 'normal' and grass stage plants were clearly evident. No attempt was made to determine the developmental origin of the secondary cortex".

The microscopic examination thus confirms and extends the ocular assessment of the differences between the two types of seedling

which are obviously adapted to completely different environments.

The growth habit of the mainland provenances is seen as an adaptation to survival under a monsoon or savanna type climate with marked seasonal water deficit, (Sub-humid: Thornthwaite), and the added threat of fire. Growth energy appears to be directed initially to the production of a thick insulating layer of bark and a protective covering of tightly-packed stout green needles which conceal the apical meristem. Not until the plant is sufficiently well established and presumably deeply enough rooted to sustain rapid growth, does elongation take place. When it does, it is relatively rapid, but uninodal and seasonal in character.

The Sumatran provenances are adapted to an equable perhumid climate (Thornthwaite classification) in which periods of moisture stress are minimal. Temperature, too, varies little throughout the year. The adaptive need in this habitat is for a growth habit suited to rapid colonisation of mineral soil in competition with ground vegetation including Imperata, Pteridium and the regeneration of numerous rainforest species, and the ability to withstand periodic fire. The marked apical dominance of the seedlings, their rapid elongation and year-round growth meets these requirements. Although the seedling bark is thin, the really vulnerable growing points rapidly pass through the 2-3 metre zone of maximum danger from fire, and the bark also thickens rapidly in proportion to tree size.

7.23 Needles (See Plates 9, 10 and 11)

7.231 Needle Length and Weight

The length and weight of five pairs of needles from 5 random trees per site at 8 sites covering the range of P. merkusii in Southeast Asia has been determined.

Needles were collected from at least five well-developed branches high in the crown in exposed positions. To ensure comparable age and stage of development the needles were taken from the first 10 cm proximal to the point of attachment of fully grown but unopened cones (i.e. those showing some signs of browning). The needles from the various branches on each tree were combined to form a composite sample per tree from which twenty random pairs of needles were retained. Of these, five were randomly selected and measured to the nearest mm, the average length being recorded if the lengths of the two needles in a pair differed by more than 2 mm. Each of the five pairs of needles per tree was then weighed to the nearest milligram. Weighing was done about nine months after collection when all needles were in a similar airdry condition. The results of the analysis of variance carried out are presented in Fig. 7

in which needle length has been plotted against weight. The confidence limits in respect of length and weight are shown for each point.

Significant differences at the 95% level were found to exist between sites and between trees. Values which do, and do not, differ significantly are indicated in Fig. 7 by the use of brackets. Also shown on the graph are needle values for two trees at Baw Luang and two at Srisaket, Thailand. These were not included in the analysis of the eight sites with five trees each, so confidence limits are not known.

There is a tendency for the values to form three groups:

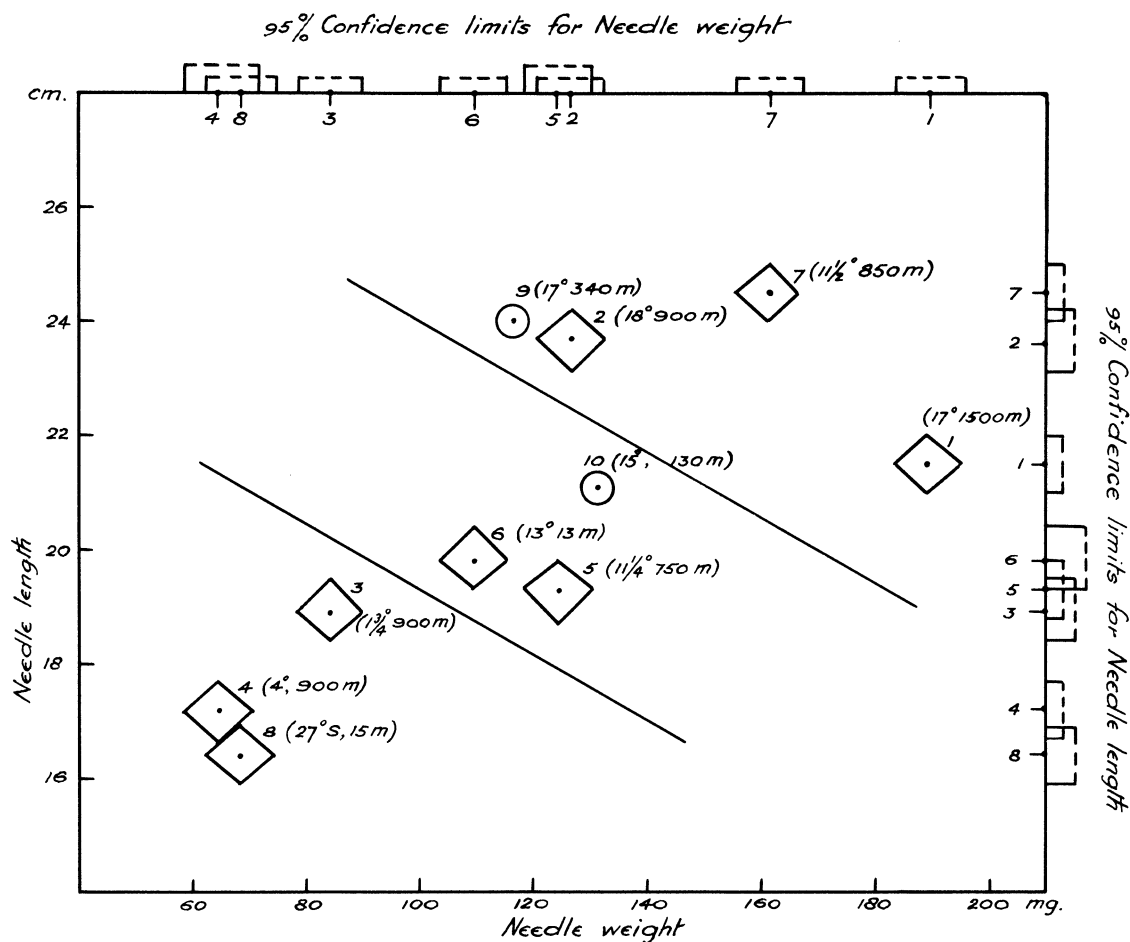
- | | | |
|-------|---|---|
| (i) | Light short needles: | Atjeh, Sumatra (Site 4)
Experiment 298 Beerburum,
Queensland (Seed ex Indonesia:
Site 8)
Tapanuli, Sumatra (Site 3) |
| (ii) | Needles of medium
length and weight: | Srakanome, Cambodia (Site 6)
Kirirom, Cambodia (Site 5)
Srisaket, Thailand (Site 10) |
| (iii) | Medium to heavy, long
needles | Tak, Thailand (Site 9)
Baw Luang, Thailand (Site 2)
Lang Hanh, Vietnam (Site 7) |

The Phu Kradoeng (Site 1) needles are heaviest of all but only of medium length. They do not conform well with the above grouping. The extremely open nature of the stand and absence of competing hardwoods may possibly account for increased needle weight; if so they should probably be included in Group (ii).

Neither needle weight nor length appears to be related to altitude as was the case with seed weight. There is no definite latitudinal trend either. On the other hand, the three groups correspond well with physiographic regions, thus:

- | | |
|---|---|
| Island of Sumatra | Group (i) Natural Forests, Tapanuli (3)
Atjeh (4); Queensland Trial Plot (8) |
| Low to medium
elevation. Korat
Plateau/Lower
Mekong Plains | Group (ii) Srakanome (6) Kirirom Plateau (5)
Srisaket (10) |

FIG. 7. NEEDLE WEIGHT/LENGTH RELATIONSHIP
IN *P. MERKUSII* PROVENANCES



1. Phu Kradoeng, Thailand
2. Baw Luang, "
3. Tapanuli, Sumatra
4. Atjeh, "
5. Kirirom, Cambodia
6. Srakanome, "
7. Lang Hanh, Vietnam
8. Beerburum, Queensland
(seed from Indonesia)
9. Tak, Thailand
10. Srisaket, "

⊙ = Sample from less than 5 trees
confidence limits not
calculated.

◊ = 95% confidence limits around
mean value.

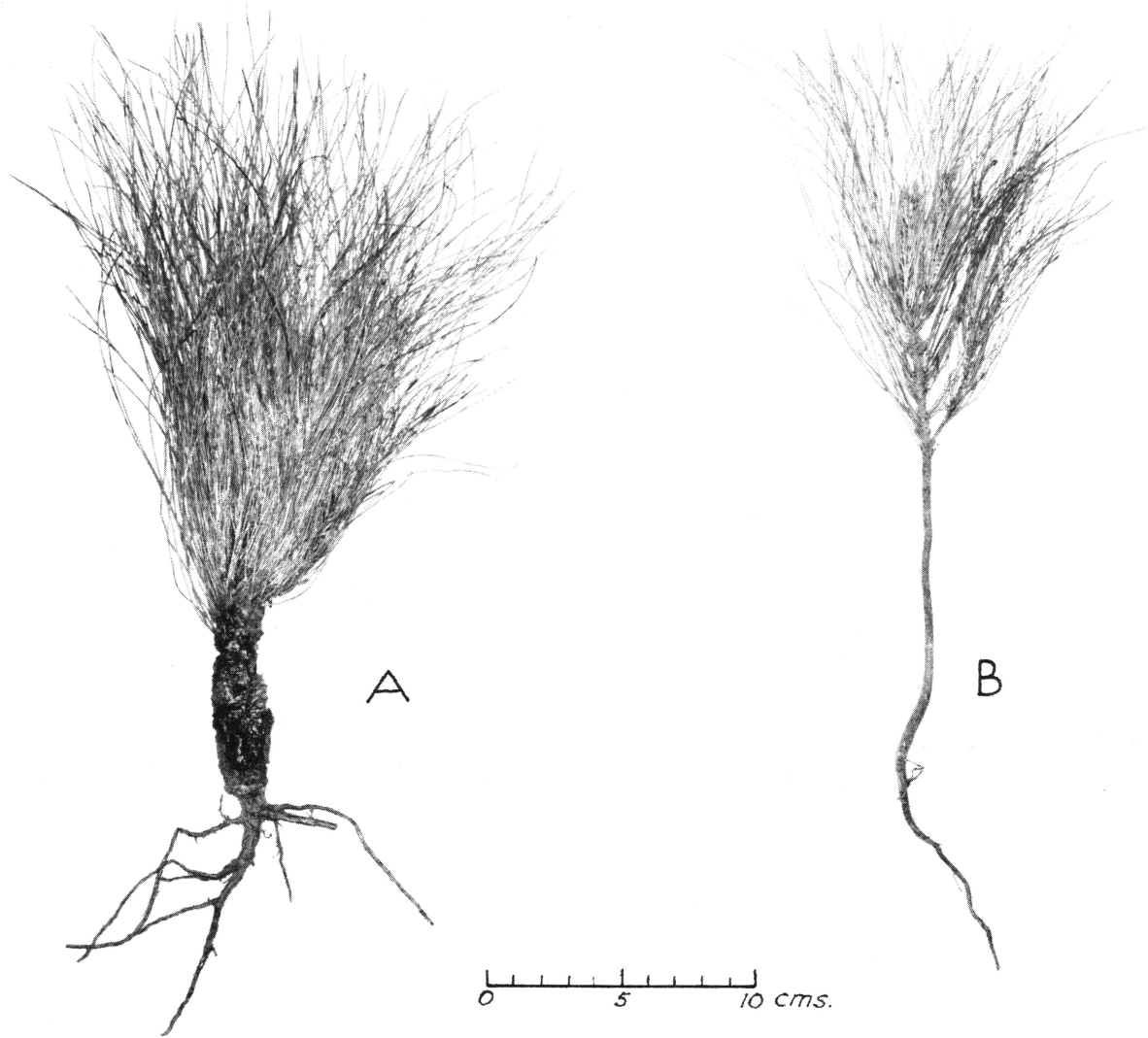


Plate 9a. Grass-stage natural seedling from mixed *P. merkusii*/*Dipterocarpus obtusifolius* forest near Lang Hanh, Vietnam. Age about 3 years. Note thick, rough, stem; dense, long needles and absence of branchlets.

Plate 9b. Seedling from natural forest at Dolok Saut, near Lake Toba, Sumatra. Tapanuli provenance, age about 2 years. Note slender, smooth, stem with no thickening; the presence of branchlets; and shorter, slender needles.

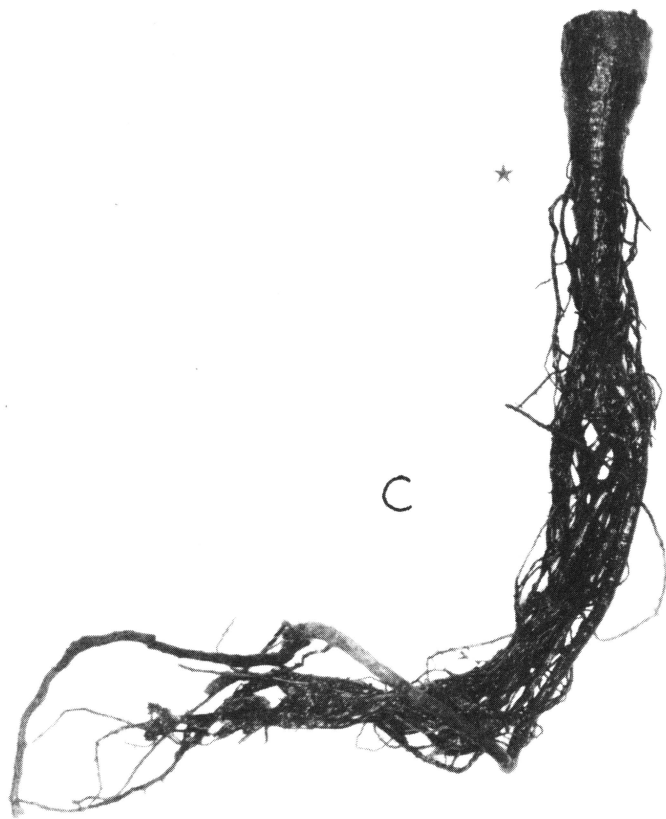


Plate 9c. Cross-section through stem of a grass-stage seedling grown in Zambia from seed of Vietnam origin. Note high proportion of bark to wood. The section was taken at the top of the specimen illustrated.

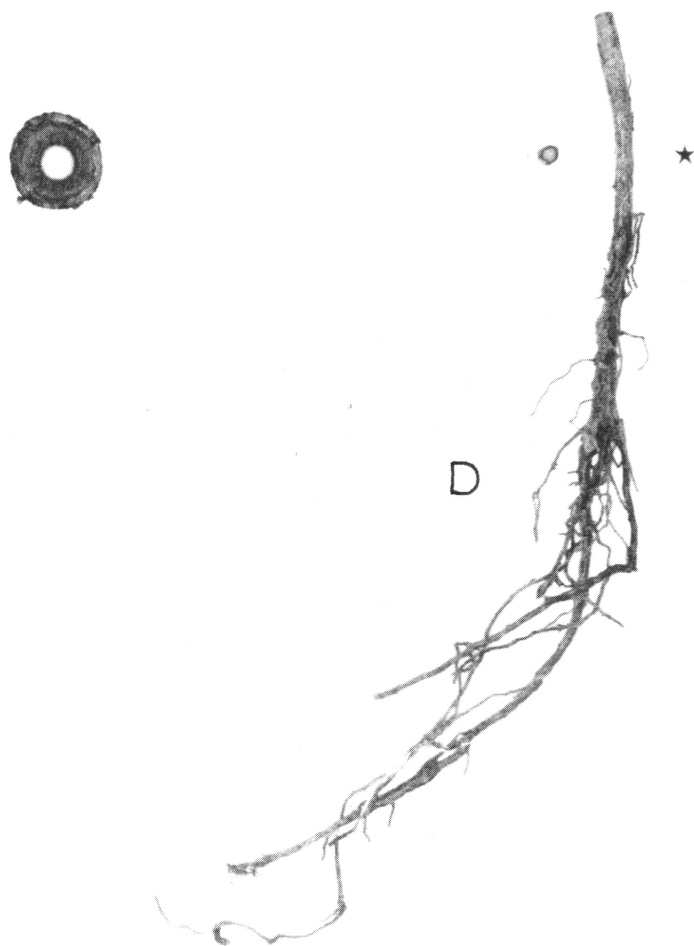


Plate 9d. Cross-section through stem of a normal seedling grown in Zambia in the same conditions and nursery as the plant in Plate 9c. This seedling was raised from seed collected in a trial plot in Zambia grown from Indonesian seed. Note high proportion of wood to bark. The section was taken at the top of the specimen illustrated.

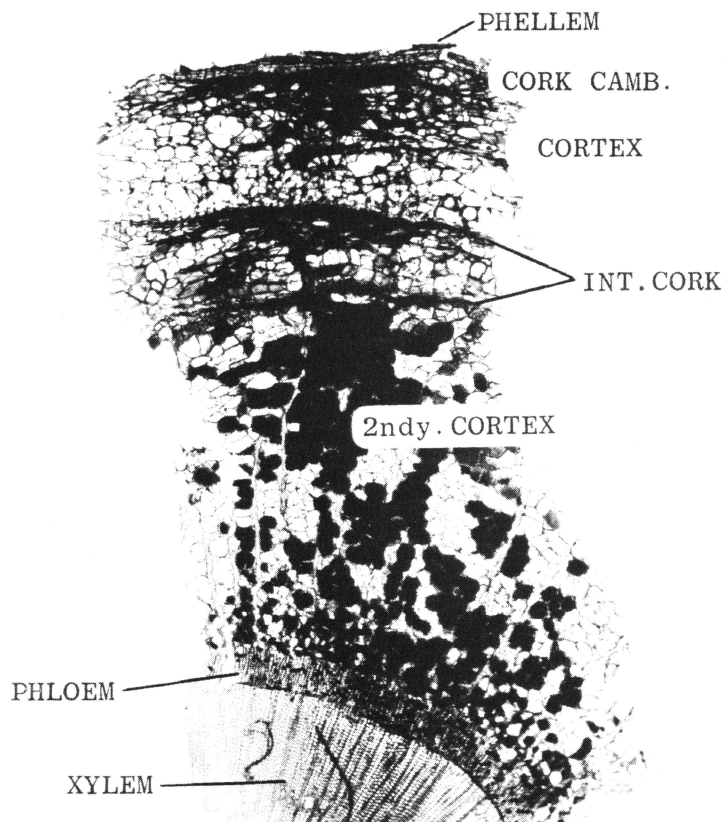


Plate 10a.

Transverse section (x 20) through stem of grass-stage seedling at about 2-5 cms above ground level. Note two zones outside phloem, (a) an outer region of primary cortex origin, (b) an inner region of secondary cortex, also inner cork layers. Xylem forms relatively small proportion of total radius.

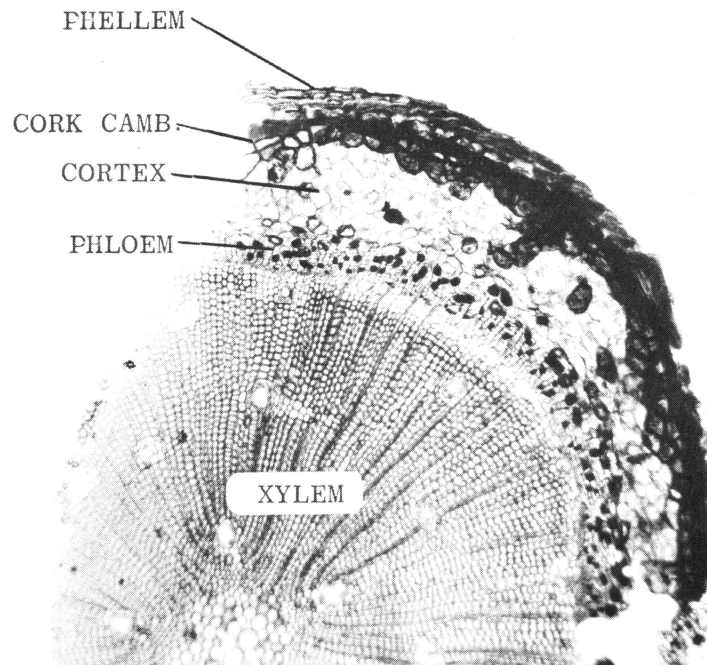


Plate 10b.

Transverse section (x 20) of 'normal' seedling, about 2-5 cms above ground level. Note absence of secondary cortex or inner cork layers and large radial proportion of xylem.

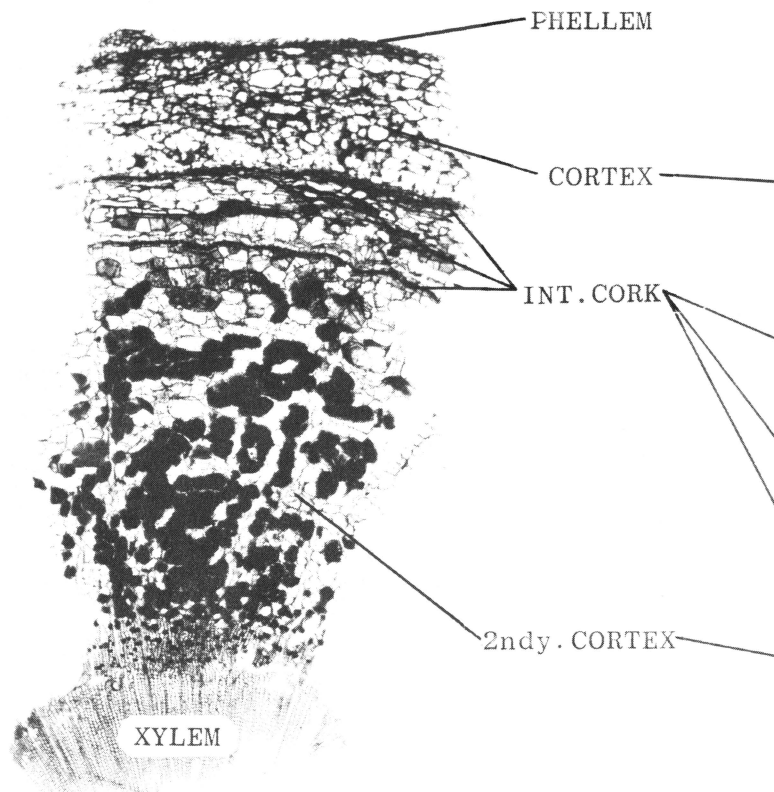


Plate 11a.

Transverse section (x 20) of grass-stage seedling. Note outer cortex; inner secondary cortex, with medullary structures continuous with the rays of the phloem; inner cork layers; and disposition of starch grains.

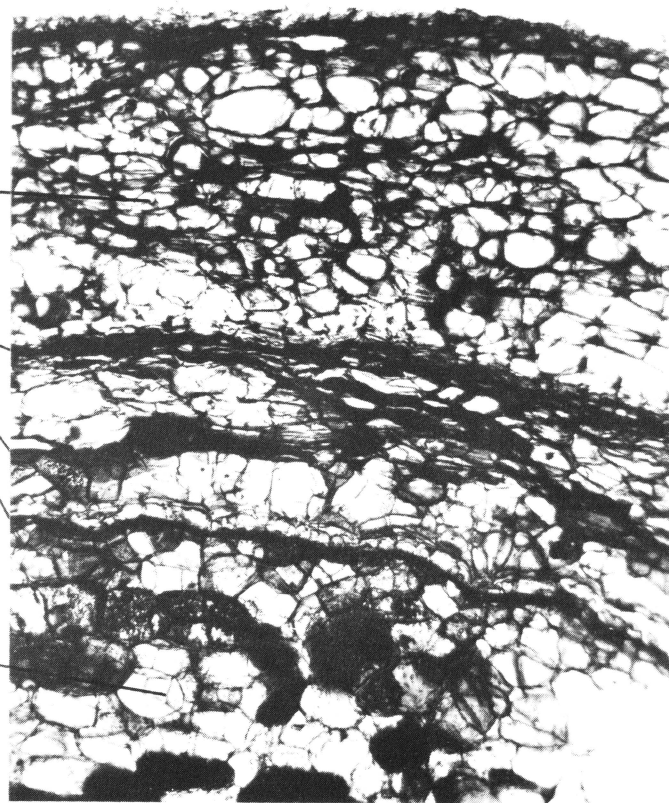


Plate 11b.

Enlarge portion of Plate 11a (x 100) showing inner cork cambium and lattice of inner cork layers.

Medium to high elevation
mountain regions sweeping in
arc from Vietnam through
Laos to North Thailand

Group (iii) Lang Hanh (7) Baw
Luang (2) Tak (9) Phu Kradoeng (1)

The needle weight/length relationship may be a means of distinguishing among those P. merkusii provenances for which the range of needle values is shown in Fig. 7 to differ significantly from others.

The differences in both length and weight are substantial: the provenances in group (iii) weigh about twice as much as those in group (i) for example.

The weight and length of the needles from the twelve year old Beerburum plot of P. merkusii, reported to be of Tapanuli origin, do not differ significantly from those of mature Atjeh specimens.

Unpublished data from Zambia give a needle length of c 18.9 cm for a seven year old plot of P. merkusii grown from seed sent from Indonesia. This is almost exactly the same as the value for mature Tapanuli provenance trees (No. 3) shown in Fig. 7. Needle length in young trial plots of Lang Hanh, Vietnam and Burmese provenances, also grown in Zambia, are respectively 28.6 and 25.9, thus placing them well up in group (iii).

This evidence suggests that needle length is reasonably constant for particular provenances even if grown as exotics under different conditions and is thus of possible diagnostic value. Precautions must be taken to ensure comparability of needles in age, physiological state and position in crown etc., and to avoid damaged needles. It appears that the method of sampling adopted was satisfactory in this respect. The efficiency of varying numbers of trees and needles is discussed in the section below.

7.232

Needle Sampling Efficiency

Taking eight sites, five trees and five pairs of needles per tree as the standard (100%), the sampling efficiency of varying the number of pairs from 2 to 20 for length determination was tested. The use of two pairs instead of five would have decreased efficiency by 2.4%; twenty pairs would have increased it by 1.2% only. A similar test in respect of weight gave a reduction of 5.8%, using two pairs of needles, and an improvement of 3.2% with twenty pairs of needles.

The effect of keeping sites constant at 8 but varying trees per site from 2 to 10 and needles from 2 to 10 per tree is illustrated by the following abbreviated extract:

Table 23

Sampling Efficiency of Varying Numbers of Trees and Needle Pairs
(taking 8 Sites, 5 Trees and 5 Needle Pairs as standard)

Sites	Trees	Needle Pairs	Length % Efficiency	Weight % Efficiency
8	2	2	- 13.1	- 35.4
8	2	5	- 8.3	- 28.3
8	2	10	- 7.5	- 25.5
8	5	2	- 2.4	- 5.8
8	5	5	Taken as the Standard	
8	5	10	+ 0.8	+ 2.1
8	8	2	+ 0.7	+ 6.4
8	8	5	+ 2.3	+ 10.9
8	8	10	+ 2.8	+ 12.5

Only two pairs of needles on five trees would not have impaired the results seriously (- 2.4%) for length determination, but would have had a greater effect on weight (- 5.8%).

Reduction in trees per site would have reduced the efficiency of the weight values by an appreciable amount (- 25% to - 35%) but would have been less serious on length (- 10%). Increasing trees per site to eight would not have increased the efficiency of the length measurements by much (2.3%) but would have been important for weight (10.9% for five needle pairs, 12.5% for twenty pairs).

7. 233

Needle Anatomy

The anatomy of the needles used for the weight determinations reported above has been investigated by O.O.Ntima with the object of determining whether or not the number and location of resin ducts was of diagnostic significance in separating the various provenances. The

variation between trees in one population and between populations is such, however, that this does not appear a promising line of investigation. In the course of his study, however, Ntima observed that whereas the vascular bundles of the majority of needles from most sites were either completely or partly fused, i. e. haploxyton, those of some of the samples from Srakanome, Cambodia, were diploxyton, while the majority of the Kirirom, Cambodia, needle sections investigated were distinctly diploxyton in character.

7. 24

Cones

7. 241

Cone Weight and Length

Cone length in cms and cone weight in grams was investigated in a similar fashion to needle length and weight and again significant differences were found between sites and between trees, Fig. 8. In this case, however, sampling was on the basis of three random cones selected from at least five but usually more per tree. Two random trees were sampled per site. No precautions could be taken as to comparability of cone location or status on the tree, but only fully mature brown, open cones free from defect were selected. The weights quoted are the airdry weights after nine months storage under laboratory conditions.

In this case the mainland provenances tend to have similar values with a fair amount of overlapping of ranges in cone weight and especially in length. The Vietnam provenance however is significantly different from all others, being about twice as heavy on average and about 30 percent longer. The other extreme is again occupied by the Sumatran provenances and the Queensland plot of Indonesian P. merkusii which are themselves similar, but differ significantly from all other provenances in weight. The Atjeh provenance is significantly shorter than all others but the Tapanuli and Queensland specimens overlap the range of most of the shorter mainland ones.

The mean length and weight of five random cones from one tree only or from an unknown number of trees have also been given but without confidence limits on the graph (Fig. 8).

The values for the Inang-Inang, Atjeh, tree corresponds well with the range for the five trees also of Atjeh provenance, while those from Tak and two locations in Laos have mean dimensions corresponding well with the majority of mainland provenances. The cones from Phu Kradoeng Plateau are, however, much larger and approach those from Lang Hanh in size.

Cone dimensions, especially weight, provide a further indication that the Sumatran provenances differ from the others. It appears

necessary, however, to treat cone parameters with some caution until more is known about the variability in size with crown position and the difference due to good and poor seed years.

7. 242 Efficiency of Cone Length and Weight Sampling

A calculation of the percentage efficiency of sampling that would result from variation in the number of trees and of cones per tree was made. This showed that, for cone weight, three rather than two trees per site would have increased efficiency by $2\frac{1}{2}\%$ to $3\frac{1}{2}\%$ and that an increase of a further 1% would have been attained with each extra tree up to 6. Increasing the number of cones to 10 would have had a smaller effect, usually to the order of 1% in the range 2 to 6 trees. For length determinations increasing tree numbers from 2 to 6 and cones from 3 to 10 would result in an improvement of 10%, to which the increase in number of cones would have contributed only about 1%.

7. 243 Cone Shape

The cones of Atjeh and Tapanuli provenances are usually cylindrical, tapering to a blunt point while the cone is still closed. Open cones are ovoid-conic in shape.

Cones of mainland provenances usually taper more strongly when closed, the widest point being at about one third length. Open cones are ovoid-conic.

7. 25 Bark (See Plates 12 and 13)

P. merkusii bark is usually very thick, deeply fissured in a predominantly vertical direction and ashen-grey in colour on the surface but reddish-brown beneath.

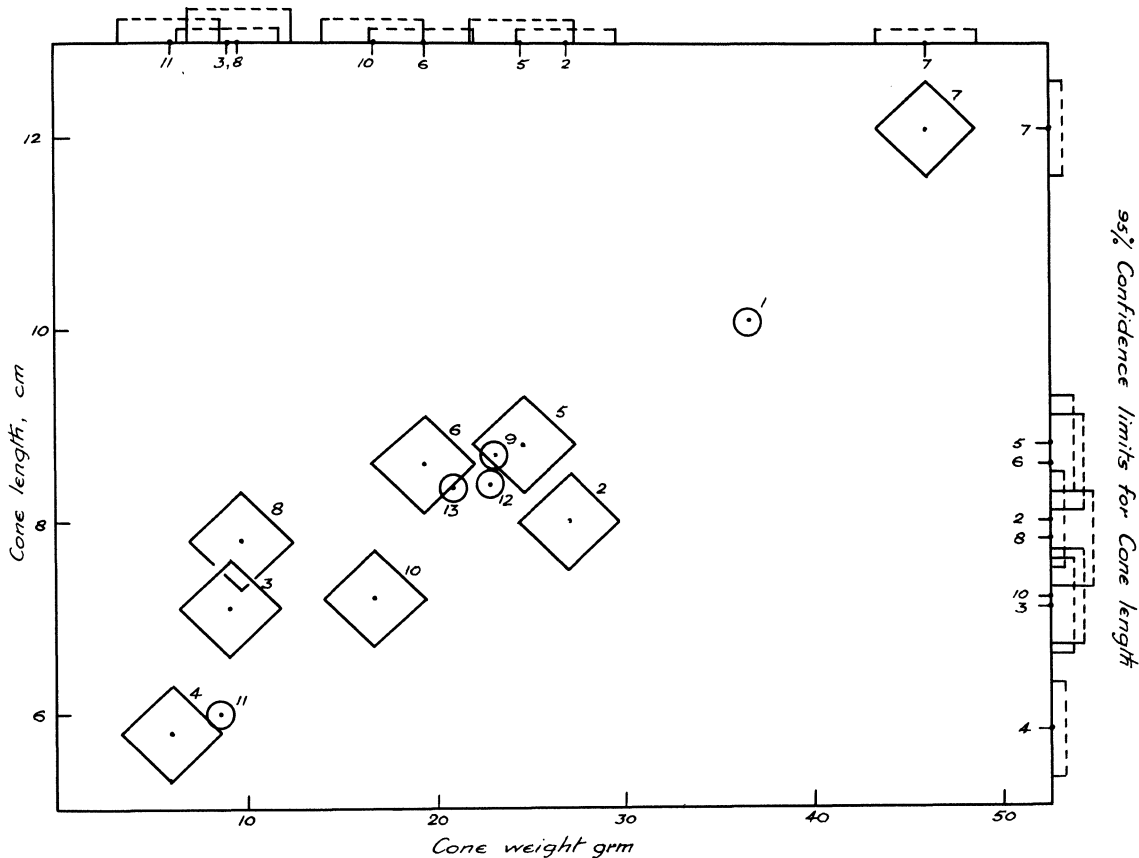
Differences in bark characteristics, chiefly thickness and roughness, have been noted by at least two observers on the mainland of Southeast Asia. Setten (pers. comm., 1967) has noted differences in the P. merkusii population on Kirirom Plateau, Cambodia (cf. Section 3. 633) while Masson (pers. comm., 1967) has done so in the Srisaket area of Thailand (cf. Section 2. 633).

Buys et al (1928) have illustrated in their photos 20 and 21 an example of relatively smooth, thin-barked P. merkusii from a mixed pine/hardwood stand and one of the thick fissured bark, typical of pines in the Atjeh blangs.

My own observations suggest that thick, fissured bark is

FIG. 8 CONE WEIGHT/LENGTH RELATIONSHIP
IN *P. MERKUSII* PROVENANCES

95% Confidence limits for Cone weight



1. Phu Kradoeng, Thailand
2. Baw Luang, "
3. Tapanuli, Sumatra
4. Atjeh, "
5. Kirirom, Cambodia
6. Srakanome, "
7. Lang Hanh, Vietnam
8. Beerburum, Queensland
(Seed from Indonesia)
9. Tak, Thailand
10. Srisaket, "

11. Inang-inang Atjeh, Sumatra
12. Done Xang Phay, Laos
13. Phou Xieng Thong, "

⊙ = Cones from 1 tree only, confidence limits not calculated.
◊ = 95% confidence limits around mean value

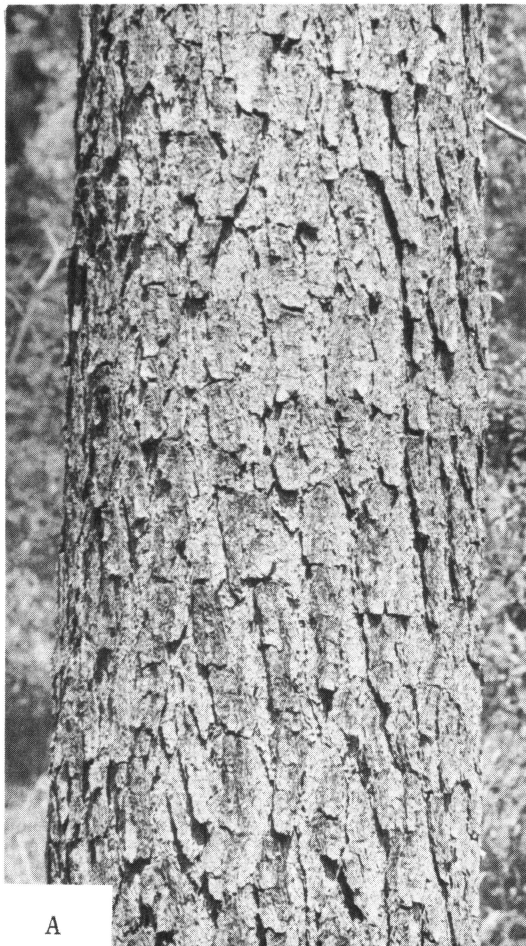


Plate 12a.

Scaly bark, not deeply fissured, characteristic of some trees in shaded positions.



Plate 12b.

Ridged bark with deep vertical fissures characteristic of trees in open positions.

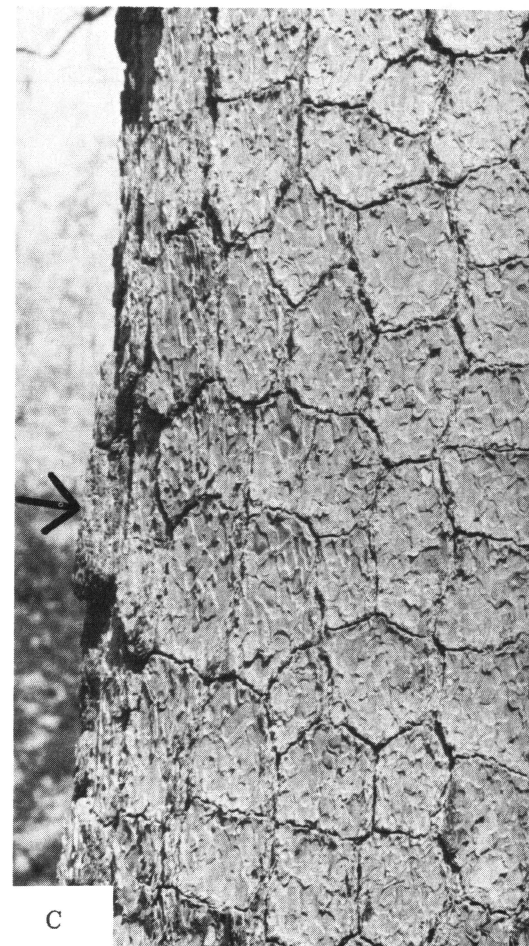


Plate 12c.

Reticulate pattern of bark cracking on trees exposed to severe fires. This pattern develops following the exfoliation of the vertical ridges as a consequence of fire damage. Note remnant of a ridge on extreme left of trunk.

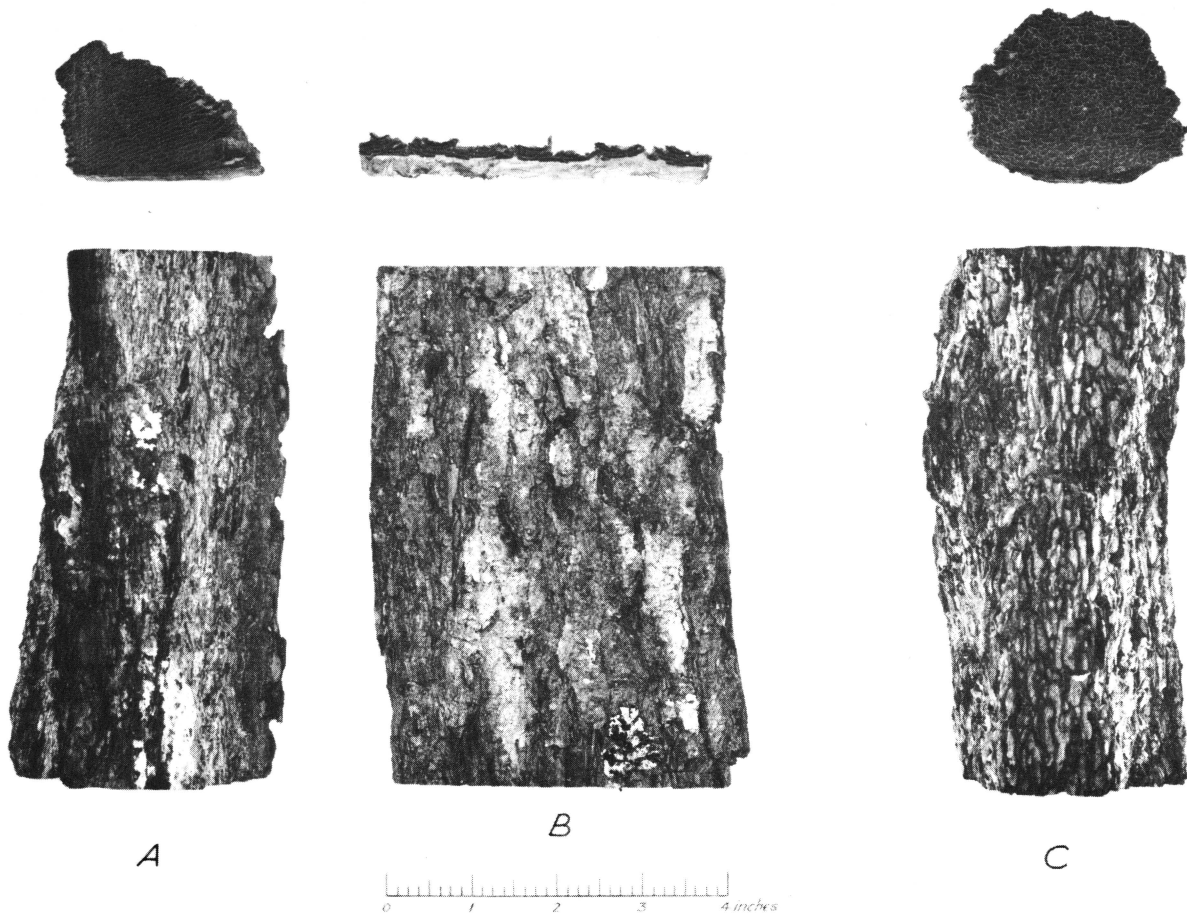


Plate 13a.

Portion of a vertical ridge of bark from a tree of Atjeh provenance. Bark is 4-6 cms thick, not including inner bark and cambium.

Plate 13b.

Typical thin, non-ridged, scaly bark of Tapanuli provenance. Thickness averages about 1 cm including inner bark and cambium.

Plate 13c.

Portion of vertical ridge of typical mainland bark from Srakanome forest, Cambodia. Average thickness about 6 cms.

typical of trees grown under relatively open conditions while those with boles continuously shaded by hardwood crowns are often moss and lichen covered and smoother, but the effect on thickness is not clear. Further, it appears that frequent severe fire may cause exfoliation of the outer ridged bark of open grown trees resulting in a thinner bark strongly fissured into angular plates, the fissures no longer having a predominantly vertical direction. This was especially noticeable in mainland forests, (see Plate 12).

The Tapanuli provenance in Sumatra forms an important exception. De Veer and Govers (1952) have reported several differences between the Atjeh and Tapanuli provenances. One major difference is in bark characteristics. These are summarised below:

<u>Tapanuli</u>	<u>Atjeh</u>
Bark thin, mostly smooth, scarcely fissured, light in colour	Bark thick, dark coloured and heavily fissured by 10 years of age

The difference is very obvious in the natural population in the field, but I did observe variation in each. In Atjeh, a very occasional smooth barked tree is to be found; in the Tapanuli forest some rougher-barked individuals do exist, but none was seen to equal a really rough-barked Atjeh tree. In plantations, however the comparison is far more striking. At Aek na Oeli there are adjacent pure stands of both provenances as well as mixed compartments. Virtually all the Atjeh trees have thick, deeply fissured dark grey bark, whereas the Tapanuli strain is conspicuous by its lighter grey and thin, somewhat scaly but unfissured bark. The difference in bark thickness is extreme. The Atjeh bark (4-6 cms) being much thicker than the Tapanuli bark (0.5-2 cms). Plate 13 illustrates typical Atjeh and typical Tapanuli bark from natural populations in Sumatra, as well as bark from Srakanome, Cambodia.

The variation in mainland provenances does not approach the order of difference found between the Tapanuli and Atjeh provenances.

In examining felled Atjeh trees, however, it was noted that the bark in the upper crown of mature Atjeh trees often has the appearance and characteristics of the bark on the lower bole of those from Tapanuli. The physiological and other significance of this is not known.

7.3 Nodal Habit and Branching

7.31 Nodal Habit

P. merkusii on the mainland of Southeast Asia is uninodal in

in habit, whereas the Sumatran provenances are strongly multinodal. This statement is based upon field observation of seedlings in the natural habitat, observations of nursery plants representing Thai, Cambodian, Vietnamese and Indonesian provenances and branch whorls/age correlations in the natural habitat and in trial plots as detailed in Table 24.

The mainland populations of P. merkusii are clearly multinodal in habit and on the evidence of Plots 343 (Vietnam provenance) and Plot 141 (Burma provenance) retain this characteristic under plantation conditions in Zambia where clean weeding and complete fire protection is in force. This conclusion is reinforced by the observation that P. merkusii of Cambodian, Burmese and Vietnamese origin in clean weeded and fertilised seed stands in Zambia is also uninodal.

All the Sumatran populations investigated and the plantation crops in Java of Sumatra origin are definitely multinodal in habit. The same is true of the plots raised from Indonesian seed in Queensland and in Zambia. The Queensland site is at low altitude (50') at Beerburrrum on the coastal strip in an area with a seasonal rainfall, while the Zambian sites are at a relatively high altitude (3700') in an area with very marked seasonal rainfall, about six months' rain and six months' dry season.

Although no supporting data can be obtained, it is reported by Bottenburg and Govers (1941) that P. merkusii of Burma origin was tested at Aek na Oeli but discarded as too slow. They record that it produced many 'lampepoetserscheuten', assumed to mean needle-clad branchless internodes, and hence possibly evidence of uninodal habit under Sumatran conditions.

There is thus much evidence that both the multinodal and uninodal habits are genotypic. Nothing is known at present to suggest otherwise.

7. 32 Branching

Allied to the differing nodal habit of the mainland and Sumatra provenances is a difference in branching characteristics.

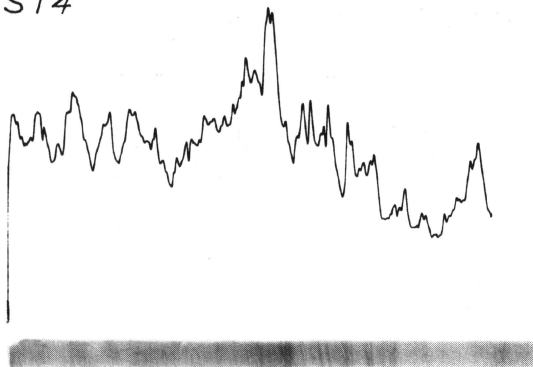
No measurements are available in this regard but on the multi-nodal trees each branch is itself more ramiform than comparable branches from uninodal trees. In combination with the differing nodal habit the difference in branchiness has a marked effect on the general crown appearance. One has no difficulty in recognising the two types in the field even in unfamiliar surroundings.

Table 24

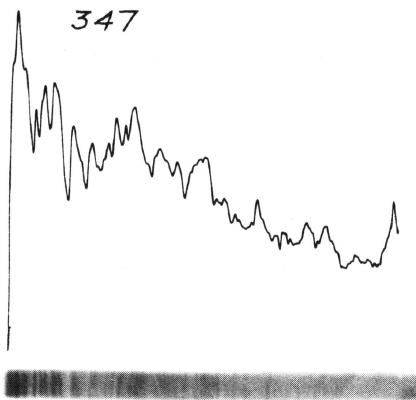
Summary of Branch Whorls/Growth Ring or Known Age Correlations

Origin	No. of Plants	Av. number of growth rings	Known age	Av. number of branch whorls	Nodal habit
Srisaket, Thailand (Natural forest, see Table 1)	5 random young trees on one site	15.5	-	15	Uninodal
Phu Kradoeng, Thailand (Natural forest, see Table 1)	"	22.9	-	22	"
Srakanome, Cambodia (Natural forest, see Table 4)	"	22	-	21	"
Kirirom, Cambodia (Natural forest, see Section 3.632)	Several trees	Not recorded	-	Approx. equal to ring counts	"
Lang Hanh, Vietnam (Natural forest, see Table 13)	5 random young trees on one site	16	-	16	"
Phou Xiang Thong, Laos (Natural forest, see Table 16)	"	20	-	20	"
Sari Plantation, N. Sumatra (See Table 19)	6 random trees in one compartment	-	8 yrs.	24.8 = 3.1 p.a.	Multi-nodal
Boer-ni-Telong Plantation, N. Sumatra (See Table 19)	5 random trees in one compartment	-	10 yrs.	35.6 = 3.6 p.a.	"
Puntjaling Plantation Tjiwidég, Java (See Table 19)	"	-	10 yrs.	28.8 = 2.9 p.a.	"
Natural forest near Lampahan Quoted by Buys et al. (1928)	1 plot of 100 young plants averaging 124.6 cms in height	-	-	Av. increment of 4 new whorls in 1 year	"
Expt. 298, Compt. 2, Res. 611, Beerburum, Queensland (Seed from Indonesia)	6 random trees in plot	-	12 yrs.	26.2 = 2.2 p.a. (Range 21-32)	"
Plot 339, Samfya, Zambia (Seed from Indonesia)	5 random trees in plot	-	9 yrs.	21.2 = 2.4 p.a. (Range 19-23)	"
Plot 343, Samfya, Zambia (Seed from Vietnam)	"	-	8 yrs.	6.2 = 1 p.a. (Range 5-7)	Uninodal
Plot 141, Dala Hill, " (Seed from Burma)	"	-	16 yrs.	14.4 = 1 p.a. (Range 14-15)	"

ST4

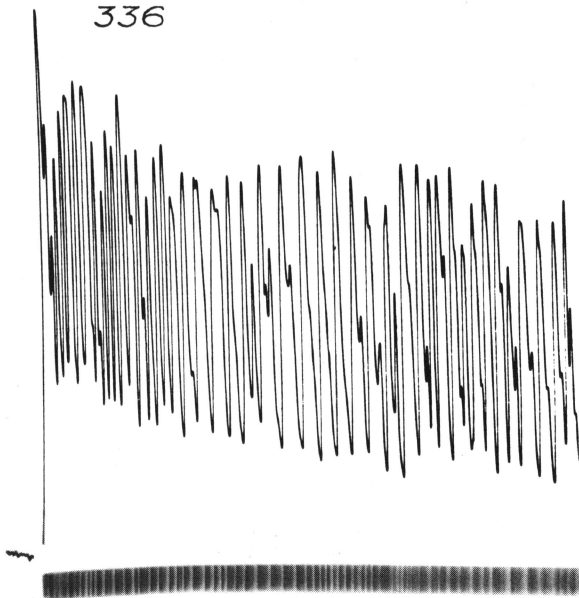


347



0 1 2 3 4 5 cms.

336



C4a

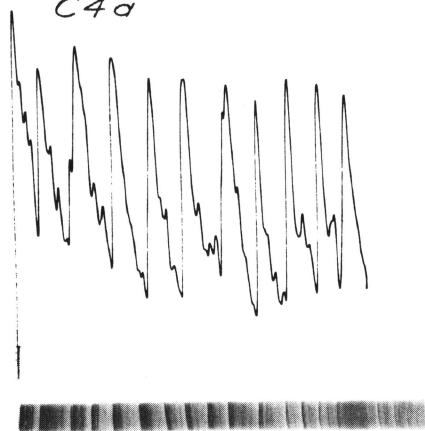


Plate 14.

Densitometer charts and prints of x-radiographs of 4 mm cores of *P. merkusii* wood.

ST4.

Tapanuli provenance, Sumatra. Mature open-grown tree. Note indistinct ring pattern in x-ray print and erratic increase and fall in chart density pattern.

347

Boer-ni-Telong Plantation, Lampahan, Sumatra. 7 year old tree. Chart and print cover radius from bark to pith. Note indistinct rings and erratic density pattern. Density variation is low across a short horizontal distance equivalent to one year's growth.

336

Tak, Thailand. Mature tree in mainland forest on road to Ban Mae Sot. Note clear but narrow rings, large amplitude of density variation within one ring and relatively high proportion of late wood.

C4a

Srakanome forest, Cambodia. Young tree, about 20 years. Note clear growth rings and large within-ring density variation. Contrast with 347 above.

7.4 Wood Characteristics (See Plate 14)

The wood of all mainland populations examined with the aid of a 4 mm Pressler borer displayed numerous growth rings made distinct by the great contrast in colour between spring and summer wood. Although very evident, the growth rings were often difficult to count with the naked eye due to close spacing and the relatively frequent occurrence of particularly narrow bands of late wood which gave the impression of false rings, either because of their narrowness, or because they did not seem to be continuous. In the natural Sumatran populations, and also their plantation grown progeny, it was found difficult or impossible to discern growth rings with any degree of assurance. Bands of differential colour or apparent density were far less frequent and, when present, often ill defined, tending to merge from one type of wood to another, or else with the assumed late-wood excessively narrow in relation to early-wood and the total core radius. Occasionally one or two well-defined rings might occur in the radius of a tree known to be say ten or twelve years old. Summaries of the ocular growth-ring determinations made in each main locality have been given under the sections 2-6.66, Rate of Growth, under the respective country heads.

More precise information on these difference was clearly desirable. Dr. J. M. Fletcher, assisted by Mr. P. G. H. Franklin, kindly investigated the density variation during the growth of particular trees by means of X-radiographs of 4 mm cores by Polge's method. The radiographs were scanned with a Joyce-Loebel Microdensiometer Mk. III CS, and charts such as those in Plate 14 were obtained.

These charts confirm the ocular evaluation of a marked difference in pattern of density variation. The nature and extent of the difference between mainland and Sumatran timber properties is obviously of considerable practical importance and calls for investigations beyond the scope of this paper.

However, it appeared desirable to quantify and describe the differential patterns as far as possible. It was decided to do so using the following data:

- (i) the amplitude of the density variation within each of a series of 10 successive rings from the bark inwards as shown on the charts,
- (ii) the ring width as determined by peak to peak measurements of the high density latewood values on the charts,

- (iii) the calculated ratio of i:ii above, i. e. the range of within-ring density variation in relation to the width between successive rings

The necessary readings of density amplitude and peak to peak distances were made and recorded in cms from the charts.

Values were obtained for a total of twelve cores representing:

3 young trees in each of 4 different mainland populations

3 young trees in a Sumatra plantation

3 young trees in a Java plantation

1 young tree in a Sumatra population

1 dominant tree in a natural Sumatra population

1 dominant tree in each of 5 different mainland populations

Within-ring density variation, ring width and the ratio of the first to the second value is given for each of the cores in Table 25.

For mainland trees the ratios for the first ten rings in from the bark are given. This was not possible with the Sumatran and Javan material owing to difficulty in determining rings. In the two natural forest trees the ratios have been derived from ten sectors of equal length using an assumed age derived from reported growth rates. In the young plantation trees the full core, bark to pith, was divided into the same number of sections as the known age of the tree in years.

Calibration of the chart patterns in terms of density was carried out by Dr. Fletcher using the superimposed pattern of a step wedge of known density.

From these values the approximate average range of within-ring density variation has been determined and is given in column 12, Table 25, in terms of the dry wood density. The approximate average density of the cores was determined gravimetrically. Expressed on the basis saturated volume/oven dry weight the results are given in column 13, Table 25. The data show that a considerable range in density within growth rings is characteristic of the mainland provenances. It appears to be accentuated with increasing age, see section (a) and (b) of Table 25. The wood of the Sumatran populations is much more homogeneous in density, again both in youth and maturity.

In the mainland provenances the chart patterns of density show typical growth ring characteristics for a conifer with increasing density from early to late wood, and an abrupt fall from the latewood peak to the beginning of the next year's early wood. Such a pattern is not clearly discernible in the charts of Sumatran samples in which density is seen to increase and to decrease in an erratic but usually gradual manner. See Plate 13 for representative examples.

TABLE 25

Comparison of within-ring density and ring widths by provenance: outer ten rings only per tree

Country	Tree No.	Variation in 'chart' density per ring expressed in cms			Growth-ring width in mms			Ratio of chart density variation: ring width			Dry wood density	
		max.	min.	av.	max.	min.	av.	max.	min.	av.	Approx. av. range	Approx. av. value (Sat.vol. o.d.w.t.)
1	2	3	4	5	6	7	8	9	10	11	12	13
A. Young trees up to ± 25 years old												
Cambodia. Srakanome	C3a	6.6	5.8	6.2	4.5	3.0	3.5	22.0	12.9	18.4	.39	.48
"	C4a	6.5	4.7	5.6	6.5	3.5	5.0	14.2	8.3	11.4	.34	.48
"	C5a	6.4	5.1	5.9	4.7	2.4	3.5	22.5	12.8	17.3	.39	.49
Thailand. Srisaket	345	6.9	3.6	5.4	5.5	2.5	4.1	20.0	8.7	13.6	.32	.41
"	346	7.0	3.6	5.6	5.5	3.0	4.5	15.9	8.2	12.6	.30	.40
"	347	6.0	4.5	5.4	6.8	3.6	4.8	15.0	8.4	11.6	.31	.53
Laos. Phou Xieng Thong	L11	6.1	4.5	5.6	3.4	2.0	2.7	27.7	16.1	21.3	.32	.49
" " "	L12	7.9	6.1	7.3	5.0	1.4	3.3	49.3	14.8	24.8	.46	.48
" " "	L13	4.8	3.6	4.5	2.5	1.2	1.7	37.5	19.2	26.7	.30	.51
Vietnam, Langh Hanh	V1	8.4	6.2	7.5	3.8	1.8	2.9	41.1	17.5	27.5	.46	.41
" "	V2	6.4	3.6	5.3	4.6	2.8	4.0	22.8	7.8	13.7	.30	.40
" "	V5	7.2	4.9	6.3	3.2	0.9	2.0	55.5	21.3	34.4	.37	.37
Sumatra. Boer ni Telong	345	3.8	0.9	2.0	-	-	7.4*	5.1	1.2	2.7	.09	.41
" " "	347	3.6	1.6	2.3	-	-	8.4*	4.3	2.1	2.8	.12	.42
" " "	348	4.5	2.2	2.4	-	-	6.7*	6.7	3.3	5.0	.14	.38
Java. Puntjaling	J1	5.2	1.7	3.2	-	-	7.5*	7.0	1.7	4.3	.14	.42
"	J2	4.5	1.2	2.5	-	-	8.5*	4.5	1.2	2.9	.11	.43
"	J3	4.7	1.2	2.3	-	-	7.2*	4.7	1.2	3.3	.16	.41
Sumatra. Tapanuli	ST7	3.0	0.5	1.5	-	-	3.7**	8.1	1.4	4.1	.09	.378
B. Mature and over-mature dominants												
Sumatra. Tapanuli	ST4	2.8	1.2	1.9	-	-	3.7***	7.5	3.2	5.1	.07	.43
Thailand. Tak	336	7.2	4.2	6.1	1.5	0.7	1.0	80.0	45.3	63.3	.32	.55
Srisaket	339	8.3	6.3	7.4	7.0	1.3	3.9	48.5	9.6	22.4	.35	.50
Phu Kradoeng	375	5.5	2.9	4.2	4.4	1.2	2.5	39.2	13.1	19.9	.23	.56
Laos. Done Xang Phay	L2	6.5	4.0	5.2	0.9	0.5	0.7	94.0	50.0	72.1	.35	.51
Phou Xieng Thong	L10	5.7	3.1	4.5	2.1	0.6	1.2	57.0	15.7	42.1	.26	.46

* Tree radius divided by known age used as ring width: rings very indistinct

** Tree radius divided into tenths: rings very indistinct

*** Age 30 assumed

Comparison of the water balance diagrams for mainland and Sumatran localities (Figs. 1-5) suggests that the much more equable climate of the latter does not provide periods of moisture stress of sufficient intensity nor of a periodicity necessary to cause appreciable annual slowing down or cessation of growth. Temperature fluctuation is also minimal.

Investigation of the wood characteristics of the two provenance groups when grown as exotics in seasonal and in equable climates is desirable as a means of determining the heritability of these characters. The differences are of sufficient magnitude to have considerable practical importance.

Further, these differences in density are paralleled by preliminary evidence of differences in tracheid length, width and wall thickness (see Appendix 3).

7. 5

Oleoresin

During the course of the tour in Southeast Asia a series of oleoresin samples was collected in most of the populations visited. It was hoped that the turpentine constituents might help to elucidate any taxonomic difficulties that might arise (Mirov, 1961, 1963, 1967).

Five random trees with well developed crowns were sampled in a representative stand in each main population. Oleoresin was obtained by drilling an upwardly inclined hole of 2.5 cms diameter for a distance of about 7 cms into the lower bole. Into this hole was screwed a stout glass specimen bottle with an outer neck diameter of c 2.5 cm. Left overnight it was usually found that about 20 ccs of oleoresin had been obtained, though tree to tree variation was apparent. The least successful attempt at sampling was at Phou Xieng Thong forest, near Khong Sedone in Laos, where only two out of five bottles contained an adequate sample after 12 hours. Two of the trees were totally 'dry'.

On removal from the trees bottles were tightly stoppered with metal screw caps lined with aluminium foil.

The oleoresin samples were submitted to the Tropical Products Institute, London for analysis. I am much indebted to the Director and to Dr. G. R. Ames for undertaking this work and for permission to quote from a preliminary report on the results. It is anticipated that a more detailed account of procedures and results will be published elsewhere. The conditions and techniques of analysis are considered to provide a

reasonable comparative assessment of the composition of the turpentine. Results are given in Tables 26 and 27. (Following para 7. 6)

If the chemical composition is to be used to distinguish between provenances then the variation between samples within a provenance must be relatively small. Some of the groups of samples meet this requirement. There is reasonable consistency for the Tapanuli, Atjeh and Atjeh 'bunga' groups and for the Srakanome (Cambodia) group. On the other hand, of the five Vietnam samples, two show a strong $\Delta 3$ - carene peak, only one a trace and two no detectable quantity of $\Delta 3$ - carene. One of the Kirirom (Cambodia) samples shows no $\Delta 3$ - carene but the other four give strong or very strong peaks for this compound. The Tak and Srisaket (Thailand) and Atjeh 'batu' (Sumatra) samples all show significant variation within the groups.

An examination of the results as a whole shows that there is no clear distinction between the Sumatran and mainland types. There is however a broad general change in composition:

- (i) at one extreme are the Tapanuli samples 1, 2, 3, 4 and 5 which consist of almost pure α - pinene (these are in fact purer than any commercial samples of α - pinene that have been examined in the Tropical Products Institute). Atjeh 4, Atjeh 'bunga' 3 (Sumatra), Tak 336 (Thailand) and Vietnam 4 are similar.
- (ii) the next simplest consist of α - pinene with various proportions of $\Delta 3$ - carene. All the remaining Sumatran samples except Tapanuli 6 are of this type as are Tak 334 (Thailand) Vietnam 3 and Phu Kradoeng (2, 3 and 4)
- (iii) at the other extreme are samples with very complex composition such as Kirirom a, b, c, d and e which contain large amounts of α - pinene and $\Delta 3$ - carene, significant amounts of β phellandrene and also β - pinene, myrcene and longifolene.

The general pattern is therefore as follows:

α - pinene only $\rightarrow$ α pinene + increasing $\Delta 3$ - carene $\rightarrow$ complex composition.

Only a few samples such as Baw Luang (Thailand) which consist of α - pinene and some β - pinene diverge from this. The Sumatran samples come on the left of this scheme and the mainland on the right. However, on the basis of these results the chemical composition alone could not be used to distinguish the Sumatran from the mainland types because:

- (i) there is no clear distinction between the sources
- (ii) in some cases there is a significant variation between samples from one source

The most which can be said is that a sample consisting almost solely of α - pinene is likely to be of Sumatran origin, while a sample of complex composition is likely to be of mainland origin. The analysis of the turpentine does however conform with the trend of other characteristics to separate the Sumatran from the mainland provenances.

Samples of Atjeh 'bunga' and 'batu' were included because the tappers distinguish these two types of tree in the field, claiming that the resin-flow of the former is better than that of the latter which is also said to have harder, heavier wood. There does not appear to be an important difference in percentage turpentine content between the two, but it appears from Table 27 that the 'batu' trees tend to contain more $\Delta 3$ - carene than the 'bunga' type. The three 'batu' trees also contained an unidentified constituent with a retention time of 31.7 cms. This was not present in the 'bunga' trees.

7.6 Geographic Distribution and Habitat

The distribution of P. merkusii in several countries in Southeast Asia has been discussed under the relevant country headings and reference has been made in 1.0 Introduction to the fact that the species ranges from the Indian Northeast Frontier Agency through mainland Southeast Asia to Sumatra and the Philippine Islands. Throughout the mainland range, and also in the Philippine locations, the climatic conditions under which the species is found are markedly seasonal in character: high or relatively high precipitation alternating with a pronounced dry season of 3 to 6 months, during which conditions of severe moisture stress usually develop (Cf. water balance diagrams, Figs. 1 to 5).

Sumatra is an exception since average monthly precipitation is above the rate of potential evapotranspiration throughout the year in representative localities (See Fig. 5).

It is true that by defining dry months in the manner proposed by Schmidt and Ferguson (1952) it may be shown that a dry season does indeed occur in the pine regions in Sumatra, but similar calculations for the mainland occurrences emphasise the dryness of those habitats even more.

The Sumatran P. merkusii populations, therefore, are distinguished not only by their disjunct geographical distribution but also by equable climatic conditions, apart from physiological, phenological and other differences.

TABLE 26

Percentage Turpentine Content of Oleoresin Samples:
P. merkusii Provenances

Origin	Tree No.	Turpentine content % (w/w)	Origin	Tree No.	Turpentine content % (w/w)
<u>Sumatra</u>			<u>Thailand</u> (cont.)		
Tapanuli	1	27.4	Phu Kradoeng	1	27.1
"	2	29.8	" "	2	20.7
"	3	27.2	" "	3	23.1
"	4	29.3	" "	4	20.8
"	5	25.3			
"	6	30.1	<u>Cambodia</u>		
Atjeh	1	27.5	Kirirom	A	23.6
"	2	28.6	"	B	22.4
"	3	24.5	"	C	20.4
"	4	26.8	"	D	22.2
"	6	28.4	"	E	21.8
Atjeh Bunga	1	27.6	Srakanome	A	25.2
"	2	24.9	"	B	21.4
"	3	31.6	"	C	21.7
Atjeh Batu	1	24.9	<u>Vietnam</u>		
"	2	26.2	Lang Hanh	1	24.9
"	3	29.4	"	2	23.8
<u>Thailand</u>			"	3	21.8
Tak	333	20.1	"	4	23.6
"	334	23.2	"	5	23.4
"	336	28.6			
Srisaket	337	24.3	<u>Laos</u>		
"	338	22.9	Phou Xieng		
"	339	20.7	Thong	374A	22.8
"	340	20.8	"	374B	21.1
"	341	21.6			
Baw Luang		24.8			

TABLE 27

Turpentine Constituents, *P. merkusii* Provenances

Turpentine Constituents		Thujene	α - Pinene	Unidentified	β - Pinene	Unidentified	Myrcene	Δ 3 - Carene	α -Phellandrene	Unidentified	β -Phellandrene	Longifolene	Unidentified	Unidentified
Retention Time (cms)		6.6	7.6	9.1	11.4	13.0	14.3	15.2	16.5	18.8	19.4	22.8	26.0	31.7
Origin	Tree No.													
Thailand														
Tak	333	T	V.S	T	T	-	T	M	-	-	-	-	-	T
"	334	-	V.S	T	T	-	T	S	-	-	-	-	-	T
"	336	-	V.S	T	T	-	T	-	-	-	-	-	-	-
Srisaket	337	-	V.S	T	W	-	W	T	-	-	-	-	-	-
"	338	-	V.S	T	W	-	W	S	-	-	-	-	-	T
"	339	-	V.S	T	W	-	W	S	-	-	-	-	-	T
"	340	-	V.S	T	W	-	T	W	-	-	-	-	-	T
"	341	-	V.S	T	W	-	T	T	-	-	-	-	-	-
Baw Luang		-	V.S	T	M	-	T	-	-	-	-	-	-	-
Phu Kradoeng	1	-	V.S	T	M	-	T	-	-	T	T	-	-	-
"	2	T	V.S	T	T	-	T	S	T	T	T	-	T	T
"	3	T	V.S	T	T	-	T	S	T	T	T	-	T	T
"	4	T	V.S	T	T	-	T	S	T	T	T	-	T	T
Cambodia														
Kirirom	A	-	V.S	T	W	-	W	V.S	T	-	M	T	T	W
"	B	-	V.S	T	W	-	W	V.S	T	-	M	T	-	T
"	C	-	V.S	T	W	T	W	V.S	T	-	M	T	-	T
"	D	-	V.S	T	W	-	W	-	-	-	S	-	-	-
"	E	-	V.S	T	W	-	W	S	-	-	S	-	-	-
Srakaname	A	-	V.S	T	M	-	W	S	-	T	T	T	-	T
"	C	-	V.S	T	M	-	W	S	-	T	T	-	-	T
"	D	-	V.S	T	M	-	W	S	-	T	T	T	-	T
Vietnam														
"	1	T	V.S	T	T	-	T	-	-	-	M	-	-	T
"	2	-	V.S	T	T	-	W	V.S	T	-	T	-	T	W
"	3	-	V.S	T	T	-	T	V.S	T	-	T	-	T	T
"	4	T	V.S	T	T	-	T	T	-	-	T	-	-	T
"	5	T	V.S	T	T	-	T	-	-	-	M	-	-	T
Laos														
Phou Xieng Thong	374-A	-	V.S	T	M	-	T	S	T	T	T	-	T	T
"	374-B	-	V.S	T	M	-	T	S	T	T	T	-	T	T
Sumatra														
Tapanuli	1	T	V.S	T	T	-	T	-	-	-	T	-	-	-
"	2	T	V.S	T	T	-	T	-	-	-	T	-	-	-
"	3	T	V.S	T	T	-	T	-	-	-	T	-	-	-
"	4	T	V.S	T	T	-	T	-	-	-	T	-	-	-
"	5	T	V.S	T	T	-	T	-	-	-	T	-	-	-
"	6	T	V.S	T	T	-	T	-	-	-	T	-	-	-
Atjeh	1	T	V.S	T	T	-	T	W	-	-	M	T	-	-
"	2	T	V.S	T	T	-	T	M	-	-	T	-	-	T
"	3	T	V.S	T	T	-	T	M	-	-	T	-	-	T
"	4	T	V.S	T	T	-	T	M	-	-	T	-	-	T
"	6	T	V.S	T	W	-	T	M	-	-	T	-	-	-
Atjeh Bunga	1	T	V.S	T	T	-	T	M	-	-	T	T	-	-
"	2	T	V.S	T	T	-	T	M	-	-	T	-	-	-
"	3	T	V.S	T	T	-	T	M	-	-	T	-	-	-
Atjeh Batu	1	T	V.S	T	T	-	T	M	-	-	T	-	-	T
"	2	T	V.S	T	T	-	T	V.S	-	-	T	T	-	T
"	3	T	V.S	T	T	-	T	S	-	-	T	-	-	T

Key to symbols: V.S. = very strong, detector response over 100. W = weak, det. resp. 5-15
 S = strong " " 45 - 100. T = trace, " " 0-5
 M = medium " " 15 - 45

7.7 Summary of Evidence of the existence of two Taxa
in P. merkusii Jungh. et de Vriese

Character	<u>P. merkusii</u> Sumatran Provenances	<u>P. merkusii</u> Continental Provenances
Seed	Small ca. 17 grms/1000	Medium-large 24-35 grms/1000
Seedlings	Slender erect stem, thin bark, little or no secondary cortex. Bark : xylem ratio 0.05 appr. Needles widely spaced on stem	Grass-like stage, very little stem elongation, but considerable thickening due to secondary cortex. Bark : xylem ratio 1.5 - 2. Primary needles in restricted collarete, secondary needles crowded at apex of stem
Growth habit	Multinodal (2-7 whorls)	Uninodal
Needles	Short, thin, light. 16-19 cm; 58-90 mg. per pair	Medium to long, sometimes very heavy. 19-25 cms 103-195 mg. per pair
Cones	Short to medium length, light. 5.2-7.6 cm; 3.2-11.7 gms. per cone. Cylindrical (unopen but mature) with bluntly pointed ends. Borne singly, in pairs, or in clusters of 3-7, occasionally up to about 20.	Medium to long, medium weight to very heavy. 6.7-12.6 cm; 14.0-48.7 grms. per cone. Elongate conic, greatest diameter at 1/3rd length (unopen, mature). Borne singly, in pairs or sometimes in threes.
Bark	May be thin and smooth especially Tapanuli provenance; Atjeh provenance bark usually thick and fissured	Usually very thick and fissured

7.7 (cont.)

Character	<u>P. merkusii</u> Sumatran Provenances	<u>P. merkusii</u> Continental Provenances
Wood	Growth rings indistinct. Density variation early:late wood slight (0.07-0.11 density units)	Growth rings conspicuous but often very narrow. Density variation early:late wood considerable (0.3-0.4 units)
Oleoresin	Usually simple chemical composition (mainly α -pinene)	Usually complex chemical composition (α -pinene, Δ 3-carene and others)
Tree size and bole form	Very tall trees to 55-60 m. Boles often slender, sinuous or spirali-form in youth, straightening with age	Tall trees to 40 m. Very sturdy straight cylindrical boles even in youth
Habitat	Equatorial (perhumid) climate 0-2 months dry	Monsoon climate (subhumid to humid). 3-6 months dry season with strong moisture deficits
Range	Island of Sumatra only. Sea level to over 2000 m but predominantly 800-2000 m.	Mainland Southeast Asia - N.W. Frontier, India - Burma - Thailand - Laos - Cambodia - and probably Philippines. Not present in Sumatra. Sea level to 900 m.

CONCLUSIONS

1. P. merkusii is a variable species, possibly a complex of 2-needled pines. Strong evidence of two separate taxa, namely the Sumatran and the mainland groups of provenances, points to the need for taxonomic review of the species. Evidence of marked variation between these two taxa has been presented in respect of: seed weight, presence or absence of a grass-stage in the seedlings, nodal habit, needle and cone dimensions, wood density patterns, oleoresin constituents, tree size and bole form, habitat and natural range.
2. The species as a whole is an example of a light demanding pioneer normally confined to poor well-drained soils (usually podsolic), but able to extend onto typical hardwood sites as a consequence of clearing for shifting cultivation and the prevalence of fire, much of it deliberately set. In Sumatra volcanism, due to the deposition of tracts of acidic tuff and the prevalence of landslides on steep slopes, is an additional factor in the spread of pine from relatively restricted sites to larger areas and into enclaves within rain forest.
3. The strong correlation between pine areas and the occurrence of poor, leached podsolic soils may explain the tendency for the mainland provenances to occur either at low altitudes between 10-250 metres or again at about 700-900 metres. These two altitudinal ranges coincide with extensive plains and plateau surfaces, generally level and pedologically senescent. The intermediate elevations are predominantly scarps and hills on which the soil is in a phase of rejuvenation due to erosion. Competition with the higher-altitude P. kesiya becomes a limiting factor at altitudes over 1000 metres.
4. The differences between the two groups of provenances are of direct practical importance. Physiological, phenological and other variation adapts these two groups to completely different environments. They should be treated quite separately in species trials and other experiments.
5. Within each of the two main provenance groups (taxa) there is further evidence of variation, sometimes clinal, sometimes ecotypic. This emphasises the need for careful attention to provenance testing, and for source identification of all seed and forest produce, including timber and oleoresin.

6. The mainland provenances of P. merkusii are well adapted to withstand fire in a seasonal climate with a marked dry season. The thick bark and stout crowded needles in the grass stage provide the necessary protection against fire and insolation while the seedling becomes established. In contrast, the seedlings of the Sumatran provenances are slender and make rapid height growth which continues throughout most of the year in the equable climate. The seedlings are thus only a short time in the fire-tender stage and, moreover, are better able to compete with hardwoods by virtue of their fast growth.
7. Mature P. merkusii trees are generally immune to fire damage due to their extremely thick bark unless the base of the bole has been damaged to the extent of exposing resinous wood. However, short cycles of shifting cultivation and regular annual fire prevent satisfactory regeneration and can cause the gradual elimination of pines leaving open depauperate woodland, savanna or grassland.
8. The Sumatran provenances are capable of very rapid growth indeed according to site quality and yield tables published for the plantations in Java (average annual increment of 14-30 cubic metres per hectare at age 20 according to site). The bulk of evidence suggests slow growth in mainland provenances although they appear to have a period of relatively rapid growth between about the seventh and thirtieth years.
9. Many reports note the general utility of P. merkusii timber and its value for constructional and decorative purposes. It is now clear, however, that an important distinction exists between Sumatran and mainland provenances in regard to annual growth rings and within-ring density variation. In the former, annual rings are indistinct or apparently absent, and density variation within sections across the radius is low. In the latter, rings are conspicuous though often tightly-spaced. Density is found to vary greatly between early and late wood. Comparative data on tracheid length are inadequate, but even assuming comparability, the difference in density patterns is sufficient to favour one or the other group for particular end uses, e. g. uniformity for pulping, variation for decorative timber.
10. Throughout its range P. merkusii is known to produce large quantities of oleoresin of good quality, but the chemical composition of the turpentine varies considerably. The Tapanuli provenance, Sumatra, has the least complex composition consisting chiefly of α -pinene while some of the mainland populations (e. g. Kirirom, Cambodia) have a complex composition and include α -pinene, β -pinene,

myrcene, Δ 3-carene, β -phellandrene among other constituents.

11. Because the two P. merkusii taxa are adapted to completely different environments care is necessary in their selection for use as exotics. In general, the Sumatran provenance is likely to succeed best in near-equatorial conditions with high rainfall and humidity and a short dry season. Given adequate soil moisture and atmospheric humidity it is well able to compete with ground vegetation and requires only light weeding. The mainland provenances are adapted to a dry season of 3 - 6 months duration and can survive low dry season humidities, but they usually occur in areas of moderate to heavy precipitation in the wet season. Their grass stage is a serious disadvantage in plantations as it prolongs the weeding period. The grass-stage commonly lasts 3 - 5 years. Thorough weeding is said to reduce its duration.
12. Both the mainland and Sumatran provenances are mainly associated with poor podsolic soils in their natural habitat, but competition by hardwoods rather than inability to grow on a range of soil types restricts them. This is especially true of the Sumatran provenance which flourishes in plantations on rich volcanic soil in Java and sometimes occurs on plains alluvia and limestone formations in Sumatra.
13. Adequate mycorrhizal inoculation is necessary for the successful establishment of this species. Special attention should be paid to this aspect in the case of the Sumatran provenance. It has been found, in Java, that the use of live 'mother trees' in the transplant beds is necessary for proper seedling inoculation even in nurseries within existing pine plantations. Inoculation with soil from established stands was not found to be satisfactory in Java but is practised in Thailand with good results.
14. Considerable scope exists for selection and breeding in this species. It may prove possible, by crossing for example, to profit from its adaptation to different environments which has resulted in slow-growing straight stems in one, and fast-growing crooked stems in another. The evidence of differential effects of Milionia attack on the Atjeh and Tapanuli provenances, reports of thick and thin-barked forms and of differences in resin productivity offer further opportunities.
15. Several factors limit the availability of sound viable seed of most provenances. The mainland group all lose viability rapidly in storage and do not stand transport well. Investigations into the physiology and storage requirements of seed of these provenances are urgently necessary. The war situation in some mainland countries also prevents or hampers the effective collection of seed in quantity.

Seed of the Sumatran provenance from the Atjeh area is readily available but the large annual planting target throughout Indonesia utilises all the seed collected under present arrangements. Specially equipped seed collecting teams could greatly increase the annual supply. Poor access limits the prospects of obtaining Tapanuli seed in bulk and there is also a need for a survey of the extent and condition of the natural forests in this area. This applies to the Kerintji population south of the Equator as well. Both may be found to be in need of measures for their long-term conservation.

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My thanks are due also to the British representatives in each of these countries for information and advice, and for assistance with the despatch of herbarium material and arrangements for the phytosanitary inspection and certification of seed.

The water balance diagrams presented in this paper have been compiled from the tables in 'Average Climatic Water Balance Data of the Continents' published by C. W. Thornthwaite Associates Laboratory of Climatology, Centerton, New Jersey, to whom I am grateful for permission to use the data in this way. Dr. Mather of the same Laboratory kindly agreed to a portion of the map 'Moisture Regions of Asia' being enlarged and redrawn to cover the area of my Survey. The original map appeared in 'Climatic Classification for Environmental Biology' (D. B. Carter and J. R. Mather, 1966).

The analyses of variance quoted were carried out by Mr. H. Wright of this Institute's Statistical Section to whom I am also indebted for several discussions concerning the interpretation of data.

The gravimetric density determinations on the 4 mm cores were made by Messrs. P. G. H. Franklin, Senior Technician and I. Gourlay, Technician, of this Institute, assisted by Mrs. J. P. Woodley, who also carried out the measurement of needle and cone dimensions. Tracheid lengths were measured by Mr. P. G. H. Franklin.

Mr. W. Rides, Senior Technician, carried out an independent ocular check in the laboratory of the ring counts made on 4 mm cores in the field. To facilitate readings one flat surface was sanded on each core. His data have been used in the tabulations of mean annual diameter increment.

I am very grateful to Mr. J. S. Shaw who has prepared for publication, from my rough drafts, all the maps and figures in this report.

Mr. C. Hatton kindly took the photographs appearing as Plates 9, 10, 11, 12 and 13. All other photographs are my own but were prepared by him for publication.

Finally, I am indeed grateful to Mrs. P. Taylor for typing the draft and final versions of this paper to a very tight schedule.

APPENDIX I. THE WATER BALANCE

Water balance diagrams have been prepared for selected stations in each of the countries covered by this report. These diagrams are based upon the average climatic water balance data published by the C. W. Thornthwaite Associates Laboratory of Climatology (1963). Reference should be made to the following publications for an account of the concept and of methods of calculating and applying the climatic water balance in environmental biology:

(i) The Water Balance

C. W. Thornthwaite and J. R. Mather. Drexel Institute of Technology, Publications in Climatology Vol. VIII, No. 1. Centerton, New Jersey, 1955.

(ii) Instructions and Tables for Computing Potential Evapotranspiration and the Water Balance

C. W. Thornthwaite and J. R. Mather. Drexel Institute of Technology, Publications in Climatology Vol. X, No. 3. Centerton, New Jersey, 1957.

(iii) Climatic Classification for Environmental Biology

D. B. Carter and J. R. Mather. C. W. Thornthwaite Associates Laboratory of Climatology, Publications in Climatology Vol. XIX, No. 4. Elmer, New Jersey, 1966.

The diagrams (Figs. 1-5) show the seasonal course of precipitation and evapotranspiration. The data included comprises:

- (i) Potential evapotranspiration
- (ii) Precipitation
- (iii) Actual evapotranspiration
- (iv) The storage of moisture in the soil
- (v) The water deficit and the water surplus

All values are expressed in millimetres and the basic data employed were computed for conditions of soil and plant cover which correspond to a soil moisture storage of 300 mm (J. R. Mather, Editor, 1963).

In the introduction to Average Climatic Water Data of the Continents, Part II Asia, the editor, J. R. Mather, writes "The actual evapotranspiration or water lost from the soil will equal the potential evapotranspiration as long as the soil moisture content is at field capacity. When the storage drops below the water holding capacity of the soil the actual loss of water from the soil drops below the potential rate proportionally. For instance when the amount of water stored in the soil is 75% of the water holding capacity, the actual evapotranspiration will be 75% of the potential. The water surplus equals the excess precipitation which occurs when the soil moisture storage equals the water holding capacity of the soil, while the water deficit is the difference between the potential and actual evapotranspiration. In areas where the 300 mm water storage capacity does not apply, for example where shallow sandy soils predominate, the computations should be re-done using the appropriate value of water holding capacity".

Instructions and tables are available to facilitate the making of computations (Thornthwaite and Mather, 1957) and recalculations have in fact been made by me in respect of several stations employing various levels of soil moisture storage considered to represent the range in natural pine sites in the climatic regions concerned. It is concluded that computations based on 300 mm storage are representative of many pine stands. Further, the general pattern of the water balance is not greatly influenced by moderate differences in moisture storage capacity, owing to the dominating effect of precipitation and potential evapotranspiration, the latter value taking account of temperature, day length, etc. The depth and texture of the soil and hence its moisture storage capacity does of course determine the relative duration and severity of the phases of soil moisture utilisation and deficit and certainly has a bearing on the likely productivity of particular sites and the ease with which it may be regenerated.

APPENDIX II

SHORT DESCRIPTIONS OF THE P. MERKUSII FORESTS VISITED IN N. SUMATRA

1. Northern Region. Bireuen to Lake Tawar

The first pines were encountered at about kilometre 39 on the road from Bireuen to Lake Tawar, which is more or less centrally situated in the northern part of Sumatra. These were mostly small groups in open blangs or in the grass near the edge of rainforest relicts. At about kilometre 50, P. merkusii occurs mixed with some hardwoods in valley heads and on the steeper valley sides which seem to have suffered some erosion and soil instability over a long period of time.

A little further on the road traverses a considerable extent of open grassy blang in which the pines occur sporadically in small groups or in ones and twos. The occurrence of pines in occasional wavy lines out in open blang attracted attention. Investigation showed that they had become established along a line of soil fracture near the crest of a slight ridge. The line of weakness was apparently subject to successive but slight landslips during earth tremors, thereby exposing mineral soil in which P. merkusii had succeeded in establishing itself.

In the vicinity of Lampahan between the still active volcano Boer Ni Telong, 2700 m, (part of the Gunung Geureudong complex) and the Peusangan river, P. merkusii is encountered in various types of forest. In the Sedong Radjavali area occasional very large trees up to some 48 m in height and 86 cms diameter are found. These are scattered through poor quality hardwood forest which has obviously been heavily exploited. Elsewhere, as on the slopes of Boer Ni Telong in the forest reserve of the same name, dense crops of almost pure pine are encountered. The stands tend to be more or less even-aged. The upper portion of the irregular cone of the volcano is bare, but pioneering ground flora may be seen here and there with P. merkusii coming in as the pioneer tree species on the middle slopes. On some parts of the lower slopes, P. merkusii is present in quite extensive stands. This is especially so in the south where, from about the 1800 m level, the pine occurs in a strip of increasing width which, on the lower slopes of the mountain, bends away to the southwest. Occasional outliers of this stand cross the main road. A good deal of the pine formation has a ground flora of grass but in some tracts bracken is abundant.

Ground vegetation is more varied in species and is taller on the lower slopes where the land flattens and occasional evidence of seepage is seen. In general, however, all the pine formations in this area are on volcanic debris and tuff described by Boys et al (1928) as very poor. There has been much interference with the forest here over a long period. At the time of the 1928 survey Buys et al

mentioned earlier gardening in the area and the fact that the lowest slopes were heavily grazed. Since then a turpentine factory has been built and some of the denser stocked areas of natural pine have been managed for resin production. Some planting has also been carried out as well as exploitation to feed a small sawmill attached to the resin factory. From Lampahan the road drops towards Lake Tawar, a long narrow lake some 17 kms long by 4 or 5 kms in width, formed as the result of the Peusangan River being blocked by a lava flow from the Boer Ni Bios. Mountain slopes rise steeply from the lake to the ridges on either side, but at each end of the lake relatively large flats permit rice cultivation. Settlement along the lake shore has resulted in considerable clearing of the hardwood forest which even in 1928 persisted only in occasional pockets. Buys et al report that large pines were then to be found only on ridge tops or singly or in small groups in the hardwood relicts. However, for a few years prior to their report, fire had been greatly curtailed on the slopes with the result that excellent regeneration was to be seen. This had started high on the ridges under the parent trees but was rapidly spreading downwards and, on the northern slopes, had reached the lake shore. In this instance the parent material was mainly limestone; but conglomerates and quartz sand and gravel also occurred. In 1967 the downward spread of regeneration was still clearly evident. Probably as a result of loss of control over fires during the intervening period a good deal of regeneration was patchy and was apparently being killed out but, within groups, some excellent growth had been made.

In the Isaq valley across the mountains to the south of Lake Toba extensive forests of P. merkusii were seen in the fairly wide but hilly valley of the Djamboe-Aje River. Here the pine was obviously associated with clearings following settlement in the valley. Pine stands, open to quite dense, surround the paddy fields and reach up into all openings in the hardwood forest. In these hardwood forests themselves however are to be seen excellent examples of the sites from which P. merkusii can seed into the blangs below. Where the road from Takingon surmounts the intervening mountain ridge to reach the Isaq valley the steep slopes are clad in dense evergreen rainforest. Here and there a landslide has carried all before it, exposing mineral soil. On these sites P. merkusii has become established but the subsequent invasion by hardwoods is already under way. As Mr. Soediarso, Director of Forest Research, Bogor, so aptly remarked "These landslides are the footholds of the pines". Other footholds and more permanent ones are to be seen on dry tuff soils on spurs and ridges, on gravelly raised terraces and similar positions where excessive drainage and soil poverty favour the more or less permanent survival of pine. Here there is often a needle-strewn floor offering good chance of pine regeneration in canopy openings. Examples of large, old pines occupying such sites are to be seen on the slopes beyond the river from the roadside near Kalisampe Camp in the Djamboe-Aje River valley.

Dominants in these secondary or blang forests are often 25 m high and about 40 cms in diameter. Stocking varies from scattered trees to dense stands estimated at 300 to 400 stems per hectare. Some areas of grassy blang with little

or no pine also occur.

2. Lake Toba Region

The plantations in the vicinity of Lake Toba have been described in Section 6. 642 Artificial Regeneration.

A difficult jeep trip was made to see the Tapanuli provenance reported near Pangaribuan south of Lake Toba. The first of these pines was sighted on the distant ridges of the Dolok Tusam to the east of a point south of Gultum village which lies beyond Siborongborong and Pangaribuan. In the same area pines were known to occur at Dolok Saut within a small nature reserve of some 40 hectares, originally created for the purpose of preserving the natural pine in mixture with hardwoods. As Buys et al suggest, this objective may be a mistaken one.

On the approach to the nature reserve from Pantoenatoloe village clumps of relict hardwoods and scattered pines were encountered on the edge of the tuff plain as the terrain became more broken. The larger trees ranged in height from about 20 to 27 m and from about 30 to 65 cms in diameter. The forest was clearly suffering from damage by fire, fuel cutting and grazing. The moderately dense and tall ground cover comprised Imperata cylindrica, Rhodomyrtus, Pteridium, Melastoma polyanthum, Lycopodium, Nepenthes and several other shrubs and herbs. Some gulley erosion was evident coming in from the tuff plain, and on the steep unstable slopes young P. merkusii ranging from current seedlings to well established saplings were relatively numerous. This narrow zone quickly gave way to closed canopy secondary hardwood forest in which large pines were locally numerous. Casuarina sumatrana was also present in local groups. No evidence of pine regeneration could be seen anywhere under the hardwood canopy. The general condition of the forest and the usually smaller dimensions of the hardwoods gave the impression of secondary growth. The likely interpretation of pine occurrence in the nature reserve is that it became established at some time in the past following the clearing or opening up of hardwood forest. Conditions then permitted the re-establishment of hardwoods which came up through a phase as understorey to become competitors. In view of their dominant status the present pines are likely to survive while their crowns remain reasonably full but thereafter may be expected to decline rapidly. No further pine regeneration is to be expected unless some factor intervenes to open the canopy again. Many of the trees seen were of good form, spiral stems being little in evidence. The majority of large trees had relatively smooth bark. On branches and on young trees it was often outstandingly so, appearing more like apple bark than pine bark.

At Gultum village near Pangaribuan, a school plantation of Tapanuli provenance planted by the Dutch in 1931 was inspected. This small stand carried a heavy stocking of large well-formed trees averaging about 55 cms in diameter (b.h.) and 40 metres in height. All had the typical light grey slightly

scaley but unfissured bark of the Tapanuli provenance. Stem-form was incomparably better than the usual Atjeh standard, and taper was slight. See Plate 8 .)

The soil was assumed to be deep acid tuff. In this area the road traverses a long expanse of relatively flat to undulating plain of very deep liparitic tuff of volcanic origin. This tuff has filled the pre-existing median trough to a considerable depth and has, in consequence, 'drowned' the flanking mountain ridges so that their present elevation above the trough floor is not great. The vegetation of the tuff plain is a highly characteristic one, comprising some grasses but many shrubs. The following were much in evidence:

Stachytarfeta jamaicensis, Rhodomyrtus sp., Ageratum sp.,
Imperata cylindrica, Pteridium aquilinum, Glycine linearis,
Melastoma polyanthum.

(Identifications by local Forest Officers.)

In some depressions a black hydromorphic soil had developed on the tuff and was said to be extremely acid.

APPENDIX III

Report on tracheid dimensions of four P. merkusii samples collected by E. N. G. Cooling

Introduction and Summary. In connection with his study of Pinus merkusii Mr. E. N. G. Cooling of the Commonwealth Forestry Institute requested the measurement of the thin and thick walled fibres of four samples of Pinus merkusii from Cambodia and Sumatra. "Tapanuli" from Sumatra was found to be distinctive.

Samples

Four samples were received which were identified as follows:

- (1) P. merkusii, Kirirom, Cambodia
- (2) P. merkusii, Batu, Sumatra
- (3) P. merkusii, Bunga, Sumatra
- (4) P. merkusii, Tapanuli, Sumatra

The woods were dissimilar in general appearance; annual growth rings appeared to be absent in the sample from Tapanuli.

Samples 2, 3 and 4 were irregular shaped blocks of wood whilst sample 1 appeared to have been cut from a plank. None of the specimens included a complete radius from centre to bark but an attempt was made to take portions representative of a radial wedge.

Experimental

These portions were then macerated by the method of Spearin and Isenberg (Science, 1947, 105, 2721), and stored in glycerol. A dilute suspension of fibres in distilled water was prepared and stained with methylene blue. Four slides were prepared from each sample and 25 determinations of length, cell diameter, and cell wall thickness (i. e. 100 per sample) were made on each. The mean values of these determinations are reported in the accompanying table together with their standard errors. The coefficient of variation is also reported for the cell diameter and cell wall thickness.

Microscopical examination

This revealed that the cell composition of each sample was quite distinctive. It was found that all but the Tapanuli contained normal early and late wood cells. In the case of the Kirirom, Cambodia sample, these were well defined and in approximately equal proportions.

The Batu, Sumatra, specimen contained a large proportion of cells that were intermediate but tending in appearance towards early wood; this could be accounted for by a gradual transition from early to intermediate and a more sudden transition from intermediate to late wood. In addition to the large proportion of intermediate cells there were a few exceptionally thin walled early and exceptionally thick walled late cells - this probably explains the high coefficient of variation.

Although intermediate cells of similar nature were also observed in the Bunga, Sumatra specimen, well defined early and late cells were also observed, the early wood cells being the predominant type.

Absence of annual rings in the Tapanuli sample was confirmed - no typical late cells were observed and only a few typical early cells were revealed. The bulk of the cells were quite uniform and were of the intermediate type resembling distorted early cells; however a few of these were tending towards late wood. This uniformity probably explains the low coefficient of variation obtained for this sample.

It is interesting to note the much shorter tracheids in the Tapanuli sample, which, together with the absence of growth-rings, clearly distinguishes it from the other samples.

Footnote: This report was received from Tropical Products Institute as the main paper was going to press.

Pinus merkusiiTracheid Measurements

	Place of Origin	Cell Length			Cell Width			Cell Wall Thickness		
		Mean mm	Standard error	Coefficient of variation %	Mean (microns)	Standard error	Coefficient of variation %	Mean (microns)	Standard error	Coefficient of variation %
1.	Kirirom Cambodia	6.35	± 0.19	30.0	54.3	± 2.07	38.1	7.81	± 0.32	41.4
2.	Batu Sumatra	5.87	± 0.20	34.5	54.5	± 1.98	36.2	8.24	± 0.39	47.0
3.	Bunga Sumatra	5.37	± 0.18	32.8	52.4	± 1.68	32.0	7.05	± 0.30	42.1
4.	Tapanuli Sumatra	3.74	± 0.10	25.7	49.9	± 1.10	22.1	6.89	± 0.17	24.7

10.0

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