OBSERVATIONS ON THE GROWTH AND CHARACTERISTICS OF CARIBBEAN PINE AT THE TEST PLANTATION ESTABLISHED IN MALAYSIA

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Introduction

Test plantation was established during the period 1971 to 1976 in order to experiment with techniques for setting up plantations and estimate the productivity for pulpwood in short rotation. Test plantation is located in Paloh, Johore in Malaysia. This land is leased through the kind cooperation from His Royal Highness Tunku Mahmood Iskander. Paloh is situated 2° 8′N, 103° 17′E, and 50-479 feet above sea level. Mean annual temperature is 78°F (25.6°C) and mean annual relative humidity is about 78%. Two slightly dry seasons occur in January-February and June-August. Soil belongs to Lateritic Red Yellow Podzolic group which is common in the tropical countries.

The test plantation was established by burning site preparation of a secondary jungle and the area totaled about 500 ha, which had been planted at the rate of 100 ha a year for 5 years.

The experiments involved in this test plantation are concentrated mainly on the establishment of *Pinus caribaea* plantation, and of its characteristics from the silvicultural point of view. Also, some experiments on fast-growing broad-leaved trees are underway.

Test plantation is set up as follows:

(1) Spacing and thinning experiment of *Pinus caribaea var. hondurensis* Barr. and Golf.	Planted in Jun., 1972	50 ha
(2) Test planting of *P. caribaea var. hond.* on the slope.	Planted in Jun., 1972	37 ha
(3) Mixed stand of *P. caribaea var. hond.* with *P. merkusii.*	Planted in Aug., 1972	86 ha
(4) Mixed stand of *P. caribaea var. hond.* with broad-leaved trees.	Planted in Mar., 1973	7 ha
	Planted in Apr., 1976	16 ha
(5) Fertilizer trial of *P. caribaea var. hond.*	Planted in Dec., 1975	9 ha
(6) Introduction of *Pinus* species and fast growing broad-leaved tree species.	Planted in 1972-1976	98 ha
(7) Soil survey.	Carried out in 1972 and 1978	

Measurements were done at the age of 2 years 6 months in 1975 and 5 years 9 months in 1978. Measurement plots were set up at many places according to the studies carried out. Usually, a plot consists of 100 trees arranged in 10×10 rows, and measurements and analysis of variance were done on total height, d.b.h., tree type (foxtailing), and other special traits. The results obtained at the young stage of a plantation are presented in this paper.

Growth of Caribbean pine

Growth of Caribbean pine was investigated in relation to spacing, to environmental factors, especially topography and soil conditions. Furthermore the growth was also analyzed for each growth state. In this investigation, tree volume and stand volume were also obtained by the preparation of a volume table, as the trees became larger than in the first investigation.

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1 Preparation of volume table

Fourty-eight trees which were thinned row-wise in close 2,000 stock plots of spacing experiments, were used for preparation of a volume table. All sample trees were cut every 1m and diameter of over- and under-bark of each small log was measured, then the volume of each sample tree was obtained by sectional measurement.

Formula $\log V = 0.9147 \log D^2H - 4.1083$ was obtained from the relation of D^2H (D; Diameter breast height, H; Height) to volume.

Standing tree volume table (over-bark) was established from this formula. Furthermore, top volume less than 7cm and bark ratio of 29.51% were calculated from sectional measurement and wood utilizing volume (under-bark) was then obtained. Although bark ratio seemed to be relatively large, this fact may be due to the calculation from the mere appearance of the diameter, namely average over-bark diameter measured by ordinary calliper. Stand volume was obtained by the use of this volume table.

2 Spacing and growth

Spacing, i.e. number of stocks per ha for planting must be selected according to the wood which will be produced in the future. For pulpwood production, many small logs of suitable size for logging and chipping under short rotation without thinning will be produced owing to the relatively large number of stocks planted. Otherwise, for better saw log production, relatively few stocks will be selected and thinning procedures will be carried out frequently.

Generally, small logs for pulpwood are produced by thinning in the process of saw log production in practical forestry.

In many countries, 1736 stocks (2.4×2.4m) per ha are usually adopted as the number of stocks for Caribbean pine for the purpose of both pulpwood and saw log production, as a number of stocks totaling 400 stocks/ha (5×5m) to 2500 stocks/ha (2×2m) is seldom adopted.

In this experimental forest, spacing experiment started first in 1972 with 3 kinds of spacing, i.e. 3.16×3.16m (1,000 stocks/ha), 2.58×2.58m (1,500 stocks per hectare) and 2.24×2.24m (2,000 stocks/ha) including thinning plans in the latter two spacings, in order to determine the most suitable methods for pulpwood production. In the first investigation, 3 years 2 months after planting, the effects of stand densities on the diameter and height increase were not recognized in the sample plots set up in each spacing. In this investigation, in the same sample plots, 5 years 9 months after planting, the effects of stand densities on the diameter of stems, crowns and clear length of stems could be recognized, as summarized as follows (Fig. 1):

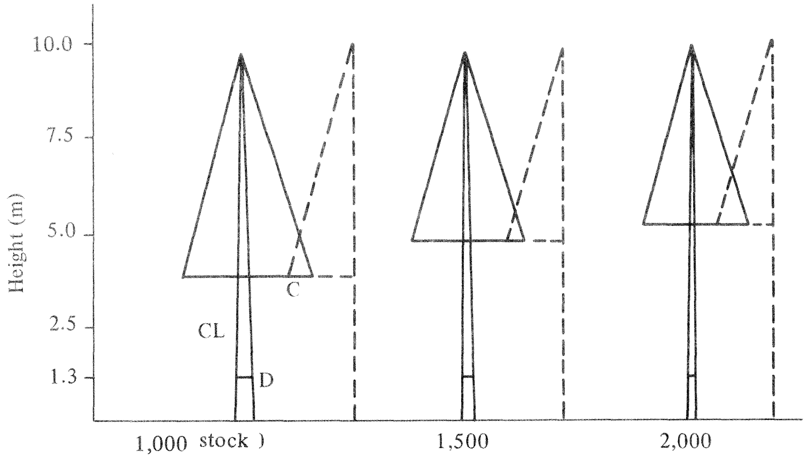
(i) The difference of height increase between spacing was scarcely recognized. Average height was about 10m.

(ii) Stem diameter at d.b.h. was larger in sparse spacing plots (1,000 stocks/ha) amounting to 16.3cm while in denser spacing lots (2,000 stocks/ha) it amounted to 13.2cm and in middle spacing plots (1,500 stocks/ha) to 14.3cm.

(iii) Crown diameter was larger in sparse spacing plots than in denser or intermediate ones, totaling 3.4m, 2.9m and 3.0m, respectively.

(iv) Clear length of stems was larger in denser spacing plots (5.2m) than middle (4.8m) and sparse (3.9m) spacing plots.

(v) Stand volume (over-bark) per ha was the same in sparse and middle spacing plots ($117m^3$) while in denser spacing plots, it was $135m^3$ owing to the large number of stocks.



	1,000	1,500	2,000
V	117	117	135
H	10.1	10.1	10.3
D	16.3	14.3	13.2
C	3.4	3.1	2.9
CL	3.9	4.8	5.2

V; Volume/ha(m^3)
H; Average height (m)
D; Av. diameter at B.H. (cm)
C; Av. diameter of crowns (m)
CL; clear length (m)

Fig. 1 Diagram showing the difference of growth and tree form among spacings (5 yrs. 9 mths. old)

3 Thinning

Row-wise thinning was carried out experimentally in every three rows at the two 2,000 stock plots, although it was recognized that it was too early to thin the spacing experimental stand from the state of crown closure and growth, and only selection of plots in which selective thinning would be done in the near future was carried out in one more 2,000 stock and 1500 stock plots, respectively.

The state of the stand before thinning was as follows: 13.8cm in average diameter, 9.3m in average height, 1,914 stocks per hectare on the average and 149.5m^3 as average stand volume at the age of 5 years 9 months. After planting and after thinning, there were 1,322 stocks per ha with a diameter of 13.7cm on average and a volume of 101m^3 on average after the thinning of 31% stocks per ha and 32% stand volume, on average (Table 1).

Smart in his report on the thinning of Caribbean pine in Malaysia, stated that the suitable time for thinning was when the basal area of the stand reached 29.8m^2/ha and a suitable method to reduce it to 23.0m^2/ha from the growth of the experimental forest in Sungei Buloh district was also indicated.

Table 1 Data from row-thinned plots
(Average value from two plots)

Before thinning	Number of stocks investigated	215
	Number of stocks which survived	199
	% of survival	92.6
	Average diameter at B.H. (cm)	13.8
	Average height (m)	9.3
	Number of stocks/ha	1,914
	Stand volume/ha (m^3)	149.5
Cut in thinning	Average diameter at B.H.	14.1
	Average height	9.4
	Number of stocks/ha	592
	Stand volume/ha	48.5
	% of number of stocks thinned	30.9
	% of volume thinned	32.4
After thinning	Average diameter at B.H.	13.7
	Average height	9.2
	Number of stocks/ha	1,322
	Stand volume/ha	101.0

Therefore, in this experimental stand the suitable time for thinning was found to occur earlier, namely 8 years after planting because the basal area before thinning was about 28.6m^2/ha calculated from average diameter and average number of stocks, as shown in Table 1 and it could be reduced to 19.5m^2 by thinning even in over-bark.

Also, according to Smart, tentative yield tables are now prepared to obtain pulpwood 15 yrs after planting without thinning from the stand in which 1,73 stocks/ha were planted. Various examples of thinning from this experimental stand will be presented in the future.

4 Growth according to topographical and site conditions.

1) Growth and topography (Test planting on slope)

In order to observe the sensitivity of the Caribbean pine to the site conditions, experimental planting was done on a slope facing the north whose soil belongs to Red Yellow Podzolic group. Measurement plots were set up in the upper and lower parts of the slope with four replications. Total height at the age of 5 years 9 months showed a significant difference (1% level) according to the position on the slope while the d.b.h. growth was not affected. Average value of total height and d.b.h. in the upper and lower parts of the slope were 7.08m, 9.27m and 11.1cm, 11.9cm respectively, therefore, growth in the lower part was superior to that in the upper part. It became clear that the growth of Caribbean pine was influenced remarkably by the soil conditions especially the effective depth of soil due to topographical location.

2) Soils of the experimental plantation

As a result of soil survey, soils of the experimental plantation were classified into Red Yellow Podzolic soil, Lateritic and Gley soils, among the great soil groups. Moreover, Red Yellow Podzolic soil was divided into three groups according to the colour or texture of the profile.

Soils of the experimental plantation
- Red-yellow podzolic soil
  - Reddish (10YR)
    - Sandy
    - Clayey
  - Yellowish (7.5YR)
- Lateritic soil
- Gley soil

There was a tendency for the distribution of these soils to be associated with the topography of the site. Red Yellow Podzolic soil covered the hilly area and extended to the periphery of the slightly undulating area in the central-eastern part of the plantation. Lateritic soil covered the undulating area in the western part of the plantation, mostly. Gley soil showed a restricted distribution, which was confined to the flat or gentle slope along the river or swampy land. Approximate acreage of each soil and percentage of the area are as follows:

Red-yellow podzolic soil	260.2 ha	52.0%
Lateritic soil	200.7	40.2
Gley soil	39.1	7.8
(Total)	(500.0 ha)	(100.0%)

As to the chemical properties of the soils, carbon, nitrogen, phisphorus potassium contents and acidity of the soil were analysed. Carbon, nitrogen phosphorus and potassium contents showed rather marked variations but there were no remarkable differences among soil types. Results of the analysis of the topsoils were as follows: Carbon content: 0.8—1.6%. Nitrogen content: 0.6—1.4% mainly, C/N ratios: 10—17. Phosphorus content showed the highest variation, being as a rule at a low level in Malaysia. Phosphorus content was 0.6—6.8 ppm. Potassium content was 27—76 ppm. Soils were very acidic with a pH (H_2O) of 4.2—4.8.

From the point of view of the physical properties of the soils, depth of soil somewhat differed among the soil types as follows:

Red-yellow podzolic soil	Reddish	Sandy	35 ~ 80 cm
		Clayey	50 ~ 60
	Yellowish		50 ~ 80
Lateritic soil			20 ~ 40 (Partly 50 ~ 60)
	(Very shallow ~ rather deep)		

3) Growth of Caribbean pine and soil

As stated above, no marked differences were found in the chemical properties of the soil in the experimental plantation depending on the soil types. As for the physical properties of soil, the effective depth of soil varied according to the soil types, to some extent.

From the data on the growth of 1 year 1 month—5-year 9-month-old stands of Caribbean pine, the following differences in the growth rate depending on the soil types and the effective depth of the soil were investigated. Moreover, in 5-year 9-month-old stand of Caribbean pine, significant correlation was found between the growth rate in tree height and the effective depth of soil throughout the soil types. At the present stage, the growth rate of Caribbean pine seems to be closely dependent on the effective depth of soil and also on the soil texture to some degree.

Mean annual increment in height increase		Effective depth of soil
2.00 m	R.Y.P.S.,* Yellowish	Deep**
1.74	R.Y.P.S., Reddish-sandy	Deep
1.65	Lateritic soil	Deep
1.58	R.Y.P.S., Reddish-sandy	Shallow***
1.29	R.Y.P.S., Reddish-clayey	Deep
1.25	Gley soil	Shallow
1.02	Lateritic soil	Shallow

* Red-yellow podzolic soil
** Effective depth more than 50 cm
*** Effective depth less than 50 cm

4) Fertilizer trial of Caribbean pine

Fertilizer trials were applied to Lateritic soil of the undulating area where the growth rate of Caribbean pine is, as a rule, poor. Fertilizer treatment was given in May for 4—6 months after planting and the height and the diameter were measured 1 year 1 month after fertilizer treatment. At the same time, the type of each tree was recorded. Fertilizers were applied in the form of a circle about 5cm deep, 30cm around the tree.

(1) Nutrient deficiency experiment with respect to nitrogen (N), phosphorus (P), potassium (K) and boron (B)

Control, N, P, B, NP, NPK, NB, NKB, PB, PKB and NBP plots were set up with four replications. Quantity of fertilizer applied with N, P, K and B as pure elements was 32.2g N in N treatment (as urea), 54.3g P_2O_5 in P treatment (as superphosphate and rock phosphate), 9.6g K_2O in K treatment (as muriate potassium) and 4.6g B_2O_3 (as boronate) per tree, respectively. The results are as follows:

	Control	N	P	B	NP	NPK	NB	NKB	PB	PKB	NPB
Height increase	100	106	130	107	115	119	115	100	130	120	123
Diameter increase	100	112	155	112	129	133	127	103	156	136	144

Distinct promotion of the growth was obtained by the fertilizer treatment with phosphorus.

(2) Experiment on appropriate quantity of fertilizer application for Caribbean pine

Control, 1/2 F, F and 2F plots were set up with four replications. Quantity of fertilizer applied in F plot was 32.2g N as urea, 54.4g P_2O_5 as superphosphate and rock phosphate, and 10.8g K_2O as muriate potassium for each tree. Quantity of fertilizer applied in 1/2 F plot was half of that in F and in 2F plot twice that in F.

Plot	Control	1/2 F	F	2F
Height increase	100	118	127	132
Diameter increase	100	128	132	149

5 Height and diameter increase by age

The oldest stand in this plantation reached 5 yrs. 11 mths. and the youngest one only 1 yr. 11 mths. Forty one plots were measured in Feb. 1978 at various experimental stands, and 25 plots among these had been measured previously in Aug. 1975. The curve indicating the increase in height and diameter was made by using the data of two sets of measurements as shown in Fig. 2.

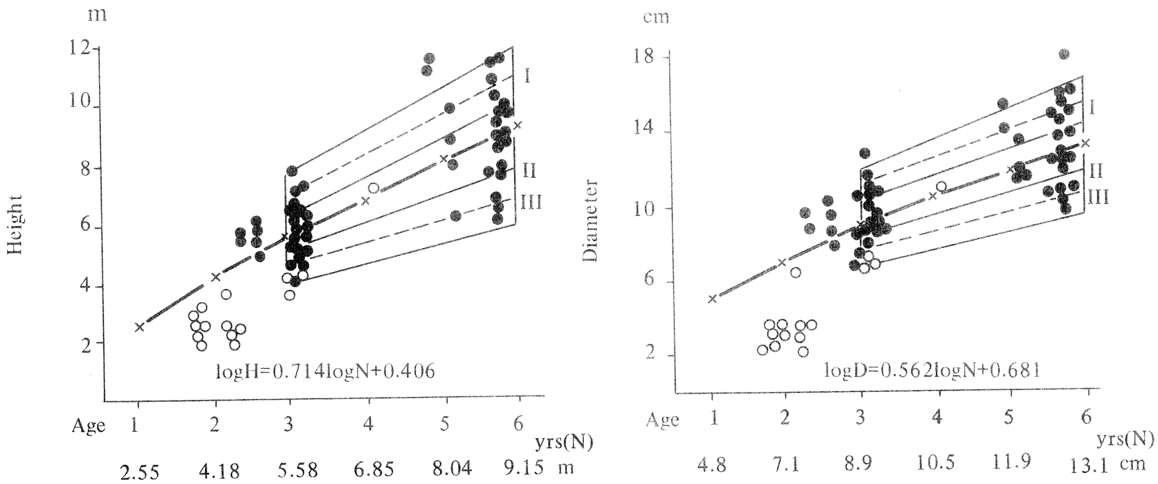


Fig. 2 Growth curve of height and diameter of Caribbean pine plantation

Black dots in this figure show growth progression depending on age in the same plot, and white dots show the results of only one measurement which was carried out in Feb. 1978. As shown in this figure, remarkable difference can be seen among plots for trees at the same age in both height and diameter increase. As regards total height, trees in maximum plot were twice as tall as those in the minimum plot in both 3-yr.-old and 6-yr.-old trees. The same results were also seen for d.b.h. showing 1.8-time difference between maximum and minimum values. Such differences in the growth could be caused by the physical and chemical properties of the soil and it can be said that Caribbean pine is sensitive to the soil conditions. On the other hand, white dots indicate plots on Lateritic soil and poor growth can be demonstrated from this figure.

6 Estimation of the amount of utilizable dry wood

Preliminary estimation was made on the amount of utilizable dry wood for pulpwood in 5-year 9-month-old trees. The data of 16 measurement plots under various site conditions involving the stands of the spacing experiment test planting on the slope and mixed planting were used for this estimation. The stand with 1.360 stocks per hectare which represents 80% of initial planting number was used because the actual mean survival of 16 measurement plots was more than 92% and a higher estimation could be expected. Volume was calculated based on the average ratio of occurrence of the tree types, namely Normal (914), Normal-Foxtailing (460) and Foxtail (7). Bark volume, which was measured on over-bark accounted for 29.6% of stem volume in an average tree/ha. This percentage was higher in comparison with the observations on other conifers. Wood density was obtained by wood chips which is the method usually adopted in paper mills. Data on Caribbean pine, as compared with the data on *Larix leptolepis* and *Abies sachalinensis* which were estimated the same way as in Caribbean pine, are shown in the following table. The growth of *Larix* and *Abies* was determined by the yield table of the plantation in Hokkaido, northern Japan.

Table 2 Estimation of the amount of utilizable dry wood

Species		V-s m^3/ha	H ; D m cm	V-w m^3/ha	Oven dry weight Dens. g/cm^3	t/ha	M.A.I. t/ha
P. caribaea var. hond.	5y-9m.	77.7	8.4 ; 12.6	48.89	0.445	21.76	3.78 (100)
Larix leptolepis	12 yrs.	79.7	9.2 ; 10.5	58.65	0.414	24.34	2.03 (54)
Abies sachalinensis	19 yrs.	80.0	7.0 ; 9.0	54.14	0.332	17.98	0.95 (25)

Remarks: V-s: Standing volume.
V-w: Utilizable wood volume.
Dens.: Oven dry weight g/cm^3, volume of wood chips dipped in water.
M.A.I.: Mean annual increment.

As indicated in the above table, the productivity of dry wood of Caribbean pine was markedly superior to that of *Larix leptolepis* and *Abies sachalinensis.* For the same standing volume, age was twice as high in *Larix* and three times in *Abies*, as compared with Caribbean pine. Also, M.A.I. of dry wood of Caribbean pine was twice as large as that of *Larix* and four times that of *Abies*.

Characteristics of Caribbean pine

The plantation of Caribbean pine shows wide variations among trees according to differences in tree height, shape and branching habits. The cause of such variations is mostly based on the foxtailing growth and the branches having needleless shoots. These characteristics are interesting and pose important problems not only from the biological but also from the silvicultural point of view.

1 Foxtailing growth

Foxtailing can be found commonly in tropical pine plantations located in the tropical zone while Caribbean pine *(Pinus caribaea var. hondurensis)* shows remarkable occurrence in comparison with the other tropical pines. Therefore foxtailing should always be considered for tending operations, growth evaluation, wood quality, etc.

1) Frequency of tree types at various sites

Measurements were performed to investigate the effect of environment on the frequency of tree type. Sixteen measurement plots were set up in three kinds of experimental plantation (spacing experiment, test planting on the slope, mixed stand) in order to analyse in a factorial design of 2 (direction of the slope, north and south) × 2 (upper and lower part of slope) × 4 (replications). In the measurements of plots, tree type was recorded for every tree, using as symbols N for the normal type, NF for trees having foxtailing part in normal growth, F for perfectly foxtailed tree. Average occurrence rate in percentage of each type was as follows:

First measurement (3 yrs 2 mths) N: 64.1, NF: 29.8, F: 6.1

Second measurement (5 yrs 9mths) N: 65.7, NF: 33.1, F: 1.2

As shown above, incidence of F type decreased from the 1st time of measurement to the second time because some of the F types showed multiple leaders at the top like a candlestick. These were recorded as NF type. However, the incidence of normal type did not vary in both measurements.

Frequency of occurrence of normal type in 16 plots under various site conditions is shown in the following table.

Table 3 Frequency of occurrence of normal type

Position on the slope	Direction	Replication				Mean			
		I	II	III	IV	North	South	Upper	Lower
Upper part	North	62.6	65.6	50.5	70.8	62.4		65.4	
	South	76.8	65.4	64.8	66.7		68.4		
Lower part	North	68.8	56.1	66.3	64.4	63.9			66.1
	South	68.1	75.6	64.9	64.2		68.2		
Mean		69.1	65.7	61.6	66.5	63.2	68.3	65.4	66.1
						(66.4)	(61.9)	(70.2)	(58.2)

According to the analysis of variance, there were no significant differences between the upper and lower parts of the slope, the northern and southern direction of the slope nor was there any interaction between position and direction of slope.

From these results, it can be considered that the effect of site condition on the occurrence of normal type is minimal suggesting that the latter is under genetic control. Considering the frequency of occurrence of the foxtailed type at various sites, the above described results can also be applied to the normal type in the same way.

2) Discussion on the cause of occurrence of foxtailing

There are many arguments about the factors at the origin of foxtailing, from the viewpoint of environment and genetics. Lückhoff (1964), Kozlowski and others (1970) and Golfari (1972) pointed out that the occurrence of foxtailing is markedly affected by climatic factors such as temperature and precipitation which vary depending on the altitude and latitude.

Ibrahim and others (1972) reported that the occurrence in Malaysia was affected by soil fertility and was higher on poor soils, showing variations with age.

On the other hand, many studies have been reported supporting the genetic point of view. Musalem and others (1973), Viersum (1973) in Costa Rica, Golfari (1972) in Brazil reported that the occurrence of foxtailing was a characteristic of species or varieties. Slee and others (1968) reported that a lower rate of occurrence of foxtailing was observed in the offsprings from seed stands in which the foxtailed trees had been removed.

In this paper I will present a hypothesis supporting the genetic point of view. According to this hypothesis which is based on monogenic inheritance, a pair of alleles is designated as A and a. The genotype of N type tree is represented by AA, F type tree is aa and NF type tree is Aa; p and q are the relative frequencies of A and a, respectively and are defined as follows:

$$p + q = 1, q = 1 - p, p = 1 - q, p^2 = 2 pq + q^2 = 1$$

In this study, as described before, the frequency of occurrence of N type was 65.7 and 64.1% in the two measurements. This result seems to be the stable ratio of tree type. Thus the frequency of N type (AA) was 0.657 as mentioned above.

Hence, AA = p^2 = 0.657, p = 0.81, q = 0.19

Genotype	Theoretical frequency	Actual frequency
AA (N)	$p^2 = 0.657$	0.657
Aa (NF)	$2pq = 0.307$	0.331
aa (F)	$q^2 = 0.036$	0.012

Actual frequency is close to the theoretical frequency. The values of p = 0.81, q = 0.19 show the frequency of Guatemala's seed provided by the Forest Research Institute of Malaysia.

3) Frequency of tree types by age

Foxtailing growth at the nursery stage cannot be identified and the youngest tree which had been seen was 6-month-old after out planting. However, it was a rare instance. Frequencies of occurrence of each tree type are shown in Fig. 3, using the data from trees which were planted in different years and which were derived from the same seed lot. As shown in Fig. 3, around 3 years of age, the frequency of N type decreased rapidly because foxtailing (NF, F types) had appeared. But at the age of 5—6 years, the ratio of each type seemed to be stabilized.

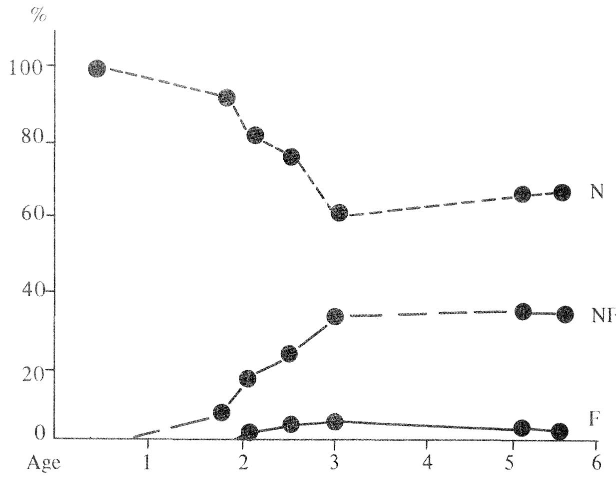


Fig. 3 Frequency of tree type by age

4) Growth by tree type

Growth according to the tree type was estimated in 16 plots with 4 replications in which the frequency of occurrence of tree type was measured as previously described.

Type	Height	D.B.H.	H/D
N	8.6	12.7	66.2
NF	9.2	11.7	78.7
Significance	n.s.	*	***

Type	Height	D.B.H.	H/D
F	11.4	10.0	117.0
NF	9.4	11.8	79.5
N	8.5	12.8	66.6

As shown in the above table, difference of growth can be seen among types. In the left side table, it is shown that there was no significant difference in total height but a highly significant difference in DBH and ratio of stem form H/D × 100 at 0.1% level was found between N and NF types. The right side table depicts the growth of F type and others in a plot, where F type had appeared although the occurrence of F type was found to be rare.

As a result, the difference in growth will be expressed as follows:

Total height	F>NF>N
D.B.H.:	F<NF<N
Ratio H/D × 100	F>NF>N

2 Needleless shoots

The absence of needles on shoots is caused by a failure of the needle fascicles to develop over a large portion of the leader or lateral shoots. In extreme cases tip dieback of the shoot can be observed.

We surveyed 16 plots, which were set up for the investigation of foxtailing growth, and results obtained are summarized as follows:

(1) Occurrence rate of trees with needleless shoots is 40.7% in the upper part of the slope, 22.8% in the lower part of the slope, and 28.2% in the slope facing the north, 35.2% in the slope facing the south. The results of the analysis of variance show that there was a significant difference at 1% level between the position on the slope, but not between the direction of the slope. On the basis of the results of the former survey, which was carried out at the age of 3 yrs. 2 mths., the average occurrence rate was 14.5% on the whole and no significant difference was observed. In the present investigation the occurrence rate increased twofold as compared with the former rate.

The occurrence of needleless shoots can be caused by site conditions, especially water content or fertility of soil according to the topography. But, the occurrence of needleless shoots seems to be a hereditary characteristic, because trees with such shoots can be distinguished individually from trees with normal leaves as both types can be found in a plot with identical site conditions.

(2) A characteristic of trees with needleless shoots is that they have male and female flowers on the shoots. Even at the age of 3 yrs. 2 mths. such trees could be seen at a rate of 43.5% in the former survey, while presently almost all of the trees with needleless shoots had flowers. It seems that in such trees the absence of needles on the shoots and flower bud differentiation are closely related.

(3) Comparison of growth was done between the trees with shoots devoid of needles and those with normal leaves. Mean total height of trees with needleless shoots was 9.1m, and that of trees with normal leaves was 8.8m, and no significant difference was found. Mean d.b.h. of trees with needleless shoots was 13.6cm and that of trees with normal leaves was 12.6cm, and a significant difference was found at 5% level.

As a result, the growth of trees with needleless shoots was not inferior to that of the trees with normal leaves.

3 Wood quality

Three samples among the three types of trees (N, NF, F) were collected for preliminary investigation of wood quality. Nine discs were taken from the base of the tree to a height of 13.3m at 2m interval and additionally at breast height. Diameter of sampled trees varied from 20.5cm to 10.5cm. Test specimens of $2cm^2$ were prepared at three areas namely central, peripheral and intermediate parts along the longest diameter, as true annual rings could not be found.

1) Basic density.

Basic density was determined by the maximum—moisture method, in reaching water saturation. Measurements were done twice before and after extraction of resin by benzol (80°C, 30 hrs.).

Basic density varies considerably within a tree, from the center to the periphery and from the base to the top as reported by Burley *et al.* (1973). The results are described in the following table.

Table 4 Basic density of portion of discs (Central, Intermediate and Peripheral) by tree type

(g/cm³)

Tree type		N			NF			F		
Portion of disc		Cent.	Int.	Out.	Cent.	Int.	Out.	Cent.	Int.	Out.
Density	Min.	0.317	0.319	0.347	0.294	0.326	0.351	0.289	0.315	0.309
	Max.	0.348	0.380	0.538	0.334	0.362	0.551	0.341	0.361	0.595
Average in all discs		0.329	0.350	0.425	0.319	0.351	0.440	0.300	0.340	0.469
1.3 m disc		0.318	0.338	0.493	0.300	0.342	0.551	0.341	0.359	0.595

Table 5 Basic density according to height (Periphery of disc in N type tree)

(g/cm³)

Height of disc	0.0 m	0.3	1.3	3.3	5.3	7.3	9.3	11.3
Density	0.538	0.527	0.493	0.433	0.390	0.346	0.347	0.325

As shown in the above table, it is obvious that the density of the periphery of the stem is higher than that of the central portion, and the density decreases according to the height of the discs. Difference of density was seen by tree type, namely the density of F type seems to be a little higher than that of the other types, as the growth of F type is inferior to that of the other types.

2) Resin content

Resin content was estimated by the difference in density before and after extraction by benzol, and the amount of resin was expressed by g/cm³ and percentage with the density before resin extraction. The results are briefly summarized as follows:

(1) Maximum resin content was 0.023 g/cm³ (4.40%) at the periphery of the basal disc, and in general, resin content was higher at the base than in the top. For a disc taken in the upper part at a height of more than 1.3m, resin content was about 0.006–0.007 g/cm³ (2%).

(2) With regard to the portion of disc, resin content at the central part was higher than that at the periphery, and when the height exceeded 5.3m there was scarcely any difference among the portions of the discs.

3) Tracheid characteristics

Traits of tracheid were assessed as the mean of 50 tracheids prepared from maceration of slivers removed in each specimen, in which the basic density was determined. Results are briefly summarized in the following table.

Table 6 Tracheid length of portion of discs by tree type

Tree type		N			NF			F		
Portion of disc		Cent.	Int.	Out.	Cent.	Int.	Out.	Cent.	Int.	Out.
Length	Min.	2.11	2.94	2.78	2.03	2.65	2.91	1.54	2.12	2.16
(mm)	Max.	2.62	3.84	4.97	2.89	3.99	4.38	2.75	3.11	4.43
Av. in all discs		2.33	3.35	4.03	2.50	3.48	3.79	2.14	2.68	3.36
1.3 m disc		2.42	3.47	4.70	2.65	3.75	3.75	2.16	2.99	4.43

Table 7 Tracheid length according to height (Periphery of disc in N type tree)

Height of discs (m)	0.0	0.3	1.3	3.3	5.3	7.3	9.3	11.3	Av.
Length (mm)	3.86	4.04	4.07	4.51	4.97	4.14	3.26	2.78	3.26

Table 8 Traits of tracheid by tree type (Periphery of disc at 1.3 m)

Type	Length (L) mm	Daimeter (D) (μ)	Wall thickness (W) (μ)	Lumen Diameter (μ)	L/D	W/D
N	4.65	51.63	7.98	35.78	90.13	0.155
NF	4.17	53.92	7.97	38.12	79.10	0.156
F	4.39	45.12	8.48	28.28	97.59	0.190

Tracheid length increased from the central portion to the periphery in the 3 types, and decreased in the discs taken from the upper part of the crown. Significant difference among tree types was not observed.

With regard to both tracheid and lumen diameters a small difference was found among tree types, namely F type showed lower values, so that L/D and W/D showed higher values than in N and NF type.

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Discussion

Wawan K. (Indonesia): Is there any correlation between fertilizer application and seed production in *Pinus caribaea*?

Answer: Flowering was observed only on trees with needleless shoots which are more frequently found on the upper part of the slope where the soil conditions are poor.

Yunus K. (Indonesia): Because of the constraints in getting good seed of *Pinus caribaea* what do you think of the applicability of tissue culture for commercial regeneration?

Answer: Tissue culture would be a useful method for propagation but seed production is preferable as it enables to maintain the wide genetic variations.

Choob K. (Thailand): What is the cause of needleless shoots in your experiment? Dis you use any herbicide? I used to observe similar symptoms on *Pinus radiata* in Australia after the aerial spraying of herbicides.

Answer: The frequency of occurrence of needleless shoots was higher in trees occupying a higher position on the slope (40.7%) than in those low on the slope (22.8%) and a significant difference at 1% level was observed. The soil conditions may also very well affect the occurrence of needleless shoots. Herbicides were only used in fire-breaks.

Tan C.H. (Malaysia): *Pinus caribaea* is a promising species for the tropical countries. However, seed procurement is becoming a problem. What would you suggest?

Answer: Although abortive seeds were observed in Paloh, sound seeds can be produced in Thailand, Indonesia and the Philippines. I therefore suggest that seed orchards be established at higher elevations.