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Growth Rates, Stem form and Branching Characteristics of Some Exotic Tropical Pines in the Shan State

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ရှမ်းပြည်နယ်ရှိနိုင်ငံခြားအပူပိုင်းထင်းရှူးသစ်မျိုးအချို့ကြီးထွားနှုန်း၊ ပင်စည်ပုံပန်းသဏ္ဌာန်နှင့်ကိုင်းထွက်ရှိမှုအနေအထားကိုစူးစမ်းလေ့လာခြင်း

ဦးစောဝင်း (B.Sc. [For.] [Rgn.], Grad. Dip. Sci. [For.] [ANU])
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စာတမ်းအကျဉ်းချုပ်

ရှမ်းပြည်နယ်တွင် ၁၉၈၀-ခုနှစ်မှစတင်၍ ထင်းရှူးစိုက်ခင်းများကို ပြည်တွင်းထင်းရှူးသစ်မျိုးဖြစ်သည့် *Pinus kesiya* ဖြင့်ကျယ်ကျယ်ပြန့်ပြန့် စိုက်ပျိုးတည်ထောင်ခဲ့ပါသည်။ ပြည်တွင်းသစ်မျိုးသည် ကြီးထွားနှုန်းနှေးကွေးပြီး ပုံသဏ္ဌာန်အားဖြင့် ကောင်းမွန်ခြင်းမရှိသဖြင့် ကြီးထွားနှုန်းမြန်ဆန်ပြီး ပုံပန်းသဏ္ဌာန်ပိုမိုကောင်းမွန်မည့် အမေရိကန်အလယ်ပိုင်းဒေသမှ အပူပိုင်းထင်းရှူးသစ်မျိုး အချို့ကို ကလောမြို့နယ်တွင် ၁၉၈၁ခုနှစ်၏ စမ်းသပ်တည်ထောင်ခဲ့ပါသည်။ စမ်းသပ်သည့်သစ်မျိုးများမှာ *Pinus patula*၊ ဒေသ(၃)မျိုးမှရရှိထားသည့် *Pinus oocarpa* နှင့် ဒေသ(၂)မျိုးမှရရှိသည့် *Pinus maximinoi* တို့ဖြစ်ကြသည်။ ၁၀နှစ်သားအရွယ်တွင် လေ့လာတွေ့ရှိချက်များအရ Honduras နှင့် Dulce Nombre ဒေသမှရရှိသော *Pinus maximinoi* သစ်မျိုးသည်ကြီးထွားနှုန်းအရ၄င်း ပုံပန်းသဏ္ဌာန် အားဖြင့်၄င်း ကိုင်းထွက်ပုံအရ၄င်း ၄င်းဒေသတွင် စိုက်ပျိုးရန်အကောင်းဆုံး ဖြစ်ကြောင်းတွေ့ရှိရပါသည်။

Growth Rates, Stem form and Branching Characteristics of Some Exotic Tropical Pines in the Shan State

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Abstracts

Pine plantations have been established on a large scale in the Shan State since 1980, using indigenous species *Pinus kesiya*. Due to the slow growth and poor form of the indigenous species, a species trial was carried out in Kalaw Township in 1981, using fast growing exotic tropical pines from Central American region. *Pinus patula*, three provenance of *Pinus oocarpa* and two provenance of *Pinus maximinoi* were put on trial. According to growth rate, stem form and branching characteristics obtained from the trails at the age of ten years, *Pinus maximinoi* from Dulce Nombre, Honduras was found to perform best in the area tested.

Contents

1. Introduction

Pine grows naturally in the hilly regions in Myanmar and pine plantations have been established extensively in these regions since 1980. This is urgently needed as the heavily cut-over natural pine resources in these hilly regions require to be replenished immediately so as to check erosion and conserve the soil. Secondly, these pine plantations will become sources of supply of raw material for the pulp and paper industry in the future. The supply of natural bamboo resource for long fibre pulp is decreasing drastically, and consequently the pulp and paper industry in looking forward to the success of these plantations as a substitute. Moreover, the cost of extraction from accessible plantations can be much lower than that from the present inaccessible natural pine stands.

The pine species being planted were mainly *Pinus kesiya*, Royle ex Gordon, which is an indigenous species. A small acreage of the same species were planted with seeds which were imported from abroad. The reason for trails with imported strains is that old plantations of *Pinus kesiya* and the natural stands exhibited very poor growth and form as compared to other fast growing tropical pines (Gyi *et al*., 1987).

As tropical pines from Central America have been introduced and planted extensively in the tropical and sub-tropical countries (Bacon and Hawkins, 1980; Hawkins *et al*., 1978; Lamb, 1973; Whitmore and Liezel, 1980) with great success due to their good growth and versatility of Timber, the Forest Research Institute has initiated trials on exotic pines in 1981, in the Shan State. The three species tested were, *Pinus patula*, *Pinus oocarpa* and *Pinus maximinoi* which were the available tropical pine species at that time. Initial assessment on the growth and survival was made in 1986, when the stand was five years old. This is a bit too early to draw any conclusions. Burley and Wood (1976) have indicated that a period of ¼ to ½ of the rotation wil be needed to draw conclusions in any species trail. However, among the species tested, initial results indicated *Pinus maximinoi* from Ducle Numbre, Honduras to be the best in the area tested (Gyi *et al*., 1987). The objective of this study is to assess the growth as well as stem form, branch size and branching habit of the various species during later stages of development, so as to find out the best substitute inplace of indigenous *Pinus kesiya* for use in plantation establishment in the Shan State.

2. Literature Review

With the rapid depletion of forested areas in the tropical and sub-tropical regions due to population pressure and land hunger, various countries in the region are trying to find ways and means to overcome this problem. One way of solving this problem is to replace the low productivity diverse natural forests with high yielding plantations of suitable species. For the purpose of selecting the best suitable species to achieve maximum productivity in forest plantations, species and provenance trials need to be carried out over a wide range of social and environmental conditions. The selection of suitable provenance is essential because when exotic species are introduced into a new environment, there is a strong tendency that there may be genetic adaptations to the local conditions (Callaham, 1964). Consequently, provenance (seed sources) trials are necessary to determine which provenance within a species are best adapted to planting in a particular new environments.

During the post-war era, plantation forestry in North America and Europe were mostly engaged in provenance research on species that are indigenous to the country or local area. Only recently, attention has been given to provenance studies on exotic species through internationally coordinated comparative trials. With the recent dramatic increase in plantation development in the tropics, exotic species stand highly in species provenance research, in terms of number of species, number of countries and number of experiments (Burley and Wood, 1976). To date, 53 countries are participating in trails of 36 provenances of *Pinus caribaea* and 44 countries in 46 provenance of *Pinus oocarpa* species (Greaves, 1981). From Asia, countries like Bangladesh, China, Taiwan, India, Indonesia, Malaysia, Nepal, Philippines, Thailand, Sri Lanka and Vietnam are actively participating in the CFI (Commonwealth Forestry institute) coordinated international provenance trials of tropical pines.

Not only Pines, but also for the broad leaved species like Teak and Gmelina, series of internationally coordinated provenance trials have also been conducted under the auspices of the Danida Forest Seed Centre (keiding *et al*., 1986; Lauridsen et al., 1987)

According to Shelbourne (1963), provenance trials of *Pinus kesiya* have been conducted in Northern Rhodesia since 1973. A comparative study was made of growth rates, stem form and branching characteristics and crown shape. The trials indicated that *Pinus kesiya* 'Assam' and 'Myanmar' were much inferior in growth tates to 'Benguet' (Philippines), 'Dalat' (S. Vietnam) and 'Madagascar' (originally some where in Indo-China). 'Benguet', 'Myanmar' and 'Assam' were inferior in stem form to 'Dalat' and 'Madagascar' being by far the best. 'Assam' and 'Myanmar' had the worst branching characteristics while 'Benguet' was slightly better than 'Dalat' and 'Madagascar'.

Provenance studies on *Pinus kesiya* were also carried out by Tozer *et al*., (1985) in the Northern Territory of Australia in 1963. *Pinus caribaea* from Honduras was included as control. provenances of *Pinus kesiya* from 'Dalat', 'Assam', Philippines (two provenances), Zambia (ex Philippines), 'Kalaw' Myanmar and Malawi were put on trial. Results from the assessment at age 9 years indicated that all the seven provenances of *Pinus kesiya* were inferior to the Caribbean pine. However, significant differences among *Pinus kesiya* provenances were also noted for mean height and number of whorls. For mean height provenance from Myanmar was the worst and 'Dalat', the best, while the Philippine and Indian provenances have the largest number of wholes per tree.

Concerning with the central American pines, *Pinus caribaea* and *Pinus oocarpa* show promise as being suitable for the economic afforestation of many degraded and naturally infertile sites throughout the tropics and sub-tropics (Graves, 1980). In 1979, seeds collected by Institute Nacionalde Investigaciones Forestales (INFI), (Mexico) from *P. oocarpa* provenances from the Central American region, for a joint cooperative trials in selective countries with INFI distributing seeds to Latin America, and the CFI distributing seeds to Asia and Africa. Based on the data base of 205 assessments from 113 trials on 26 countries for the *P. caribaea* investigations, and 116 assessments from 77 trials in 24 countries for *P. oocarpa*, studies revealed that several provenances for both species showed consistent trends over a wide range of sites when ranked according to vigour, crown and stem form. The three varieties of *P. caribaea* occurred in the order var. *caribaea*, var. *bahamensis* and var. *hondurensis* when ranked according to increasing height growth, and in the reserve order for improving stem and crown form (Greaves, 1981). Height distinctive differences in vigour and stem and crown form were apparent among several *P. oocarpa* provenances within one year of plantating. Fox-tails were only a characteristics of the Mountain Pine Ridge provenance from Belized which together with several provenance from Nicaragua at the Southern limit of the species range, was conspicuous for its rapid growth rate and a high proportion of well formed trees (Greaves, 1980).

Pinus patula is the other conifer species performing quite successfully in many parts of Southern and Eastern Africa, though success is mainly restricted to high altitude areas (Adegbehin, 1982). Barnes and Styles (1983) also stated that *Pinus patula* has been a very successful exotic species due to its desirable characteristics. It has been quite successfully planted off-site at low altitude in the tropics. In such situations it often has outstanding initial performance. However, after about ten years it becomes coarse and unthrifly and progressively more susceptible to disease and insect attack, resulting in a light misshape unhealthy crown.

Quite recently a complex species designated *Pinus pseudostrobus* has been included in the international provenance trails organized by CFI. Provenance seed collections made for these trails were later found to include two taxa, *Pinus maximinoi* and *Pinus preudostrobus.* These two taxa per form quite differently: the group of provenances from Nicaragua, Honduras and including one from Guatemala (K 63) showed a phenotype with a symmetrical crown of fine branches, with fine buds covered by, long thin needles which tend to droop. The other of provenances from Mexico and Guatemala (K 75) has a long, thick buds and long coarser needles than the first group. All the provenances showed reasonable survival but there was a noticable difference in height growth between the two groups. Trees from the first group, later renamed as *Pinus maximinoi*, were much taller than from the second group, which represents *Pinus pseudostrobus* (Stead, 1983). Assessments of trials have been carried out in Thailand (Anon, 1978), Honduras (Houkal, 1980) and South Africa (van der Sijde, 1980).

3. Materials and Methods

The trial was carried out at Kalaw public forests at Pinlaung junction, Kalaw Township, in 1981. For planting, the standard site preparation method used in the Shan State, was adopted, i.e, felling, burning, kyunkwe and staking; 1' x 1' x 1' pits were dug at each stake. The spacing adopted was 9' x 9' which was the standard spacing at that time. Three weedings were carried out in the first year, two in the second and the third year and one in the fourth year.

The species and provenances tested were as stated below:-

Lot No.	Species	Provenance	Latitude
102 (Oo)	*Pinus oocarpa*	Nicaragua	12˙ 15" N
106 (Oo)	*Pinus oocarpa*	Honduras	14˙ 54" N
107 (Oo)	*Pinus oocarpa*	Guatemala	15˙ 22" N
110 (Pm)	*Pinus Maximinoi*	Honduras	14˙ 48" N
111 (Pm)	*Pinus maximinoi*	Honduras	14˙ 52" N
095 (Pp)	*Pinus patula*	Not avalilable	-

(See Appendix 1 for detail)

Randomized complete block design was used in conducting this experiment. However, due to lack of sufficient number of seedlings, the trial was replicated only twice. One block was situated on the upper slope while the other was situated on the lower slope. Each block contains six plots and each plot contains 6 x 30 = 180 seedlings of each species and provenances listed above.

3.1 Growth Rates

Each plot consists of 0.2 acre in area. Within each plot 10 dominant trees were measured for height. Height of trees were measured to the nearest inch by telescopic height rods. Diameters were measured to the nearest 0.1 inch by diameter tapes. Plot mean height and mean diameter were converted to Mean Annual Height Increment (MAHI) and Mean Annual Diameter Increment (MADI), by dividing with age. Number of whorls per tree were also recorded from these trees for the determination of average number of whorls per tree.

In order to make a rough comparison on the performance of exotic tropical pines with indigenous *P. kesiya* planted in the Shan State, height and breast height diameter of 50 trees were measured from the *P. kesiya* plantation of same age adjacent to the experimental plot.

3.2 Stem form and Branching Characteristics

For each standing tree in the plot the following characteristics were also recorded:-

1. Sinuosity
2. Butt sweep
3. Basal sweep
4. Forked stems
5. Flop
6. Multiple stems
7. Broken crown
8. Foxtailing

Also recorded were the incidence of flowering and fruiting for each standing tree in the plot.

Pruning and thinning were carried out along with the assessment. Trees were pruned to approximately 1/3 of the height (roughly up to 10') while thinning was carried out from below leaving roughly around 300 trees per acre. From every third tree thinned, a five foot section was selected from 10-15 feet above ground. In this section the number of branches of each whorl and the diameter of all branches in the bottom whorl were recorded. Branches per whorl and branch diameter were derived from the recorded date.

To compensate for the decrease in branch diameter with height, mean branch diameter is divided by height to give a comparable ratio. This branch diameter ratio multiplied by branches per whorl which indicates total number and diameter of future knots.

Branch angle was also estimated from the bottom whorl ocularly within the following ranges 15˙, 30˙, 45˙, 50˙ and 90˙ with the horizontal. The higher the branch angle the more flatten the branch will be. Low angled branches are not desirable as they tend to develop severe knots.

3.4 Method of Analysis

In order to find out which of the species/provenances produce better yields, height, diameter and basal area per acre will be used as criteria to judge the differences. Test of difference between species/provenances which have been ranked in order or magnitude of their mean values, will be made using Duncan's Multiple Range tests. The procedure for testing using Duncan's method is as follows:-

1. The population means were ranked in order of magnitude.
2. To test the difference among a sequence of k mean values, the critical difference was computed according to the formula-

$$C = {}^{k}_{v} Qp \text{ x } s_k \text{ (mean)}$$

in which Qp is the tabulated value of the studentised range of the Duncan's statistic for a range of k means, v, residual degrees of freedom and significant level p.

The test is usually applied sequentially to identify group of mean values which do not differ significantly. Such groups may be identified by a bar spanning them.

4. Results

The results of average height, average diameter, mean annual height growth, mean annual diameter growth and based area growth per acre for each tested species are given in Table 1, and those of branch characteristics for individual species in Table 2. Block wise estimates are given in appendix 2. The average height and diameter of *Pinus kesiya* from the plantation area adjacent to the experimental plot were 15.47' and 4.25" respectively.

Table 1. Number, height, diameter and basal area growth of tested species.

Sr.No	Species	N	D (in)	H (ft)	B.A/ac (sq.ft)	MADI (in)	MADI (ft)
1	Pm (111)	120	5.81	36.80	92.27	0.58	3.68
2	Pm (110)	89	5.17	32.10	55.26	0.52	3.21
3	Po (102)	46	6.07	37.43	40.43	0.61	3.74
4	Po (106)	63	4.43	26.65	28.97	0.44	2.67
5	Po (107)	86	4.71	27.29	48.05	0.47	2.73
6	Pp (095)	52	4.99	28.42	28.89	0.05	2.84

Table 2. Branch Characteristics of tested species.

Sr. No.	Species	Average number of whorls			Branches per whorl	Branch dia (in)	Converted total br. dia/ whorl	Branch angle (deg.)
		Per tree	Per annum	Per foot				
1	Pm (111)	16.4	1.64	0.42	2.67	1.0	0.072	58.66
2	Pm (110)	16.5	1.65	0.52	2.50	1.1	0.085	79.86
3	Po (102)	20.3	2.03	0.53	2.91	0.8	0.061	66.32
4	Po (106)	14.4	1.44	0.50	3.33	0.9	0.101	79.80
5	Po (107)	18.7	1.87	0.62	3.06	0.9	0.101	71.67
6	Pp (095)	19.7	1.97	0.60	2.75	1.0	0.096	50.45

Assessment on stem defects, fruiting and flowering were also presented in Table 3.

Table 3. Incidence of stem defects, flowering and fruiting .

Sr. No.	Species	Stem defects (%)								Fruiting and Flowering (%)	
		S	B	BS	F	Fr	F1	Ms	Bc	Ft	Fw
1.	Pm (111)	2	81	3	8	19	12	2	-	43	-
2.	Pm (110)	12	88	10	8	42	18	2	-	22	-
3.	Po (102)	11	68	8	3	11	16	-	3	24	3
4.	Po (106)	16	70	2	5	9	11	-	-	-	2
5.	Po (107)	28	48	13	-	13	-	-	-	40	-
6.	Pp (095)	-	89	-	-	47	-	-	-	58	-

Where, S = Sinuosity, B = Buttsweep, BS =Basal sweep, F = Foxtailing, Fr = Forking, Fl = Flop,
Ms = Multiple stems, Bc =Broken crown, Ft = Fruiting, Fw = Flowering.

4.1 Height

When comparing height growth of the tested species and pronvances using Duncan's method of analysis, three overlapping groups were apparent. It can generally be stated that lot no. Po (102); Pm (111) and Pm (110) tended to be better in height growth than Pp (095), Po (106) and Po (107). Raking are given below with lines liking those that were not significently different.

Height (ft) 1991

Sr. No.	Species	Height	DMRT (95%)
1.	Po (102)	37.43	
2.	Pm (111)	36.80	
3.	Pm (110)	32.10	
4.	Pp (095)	28.42	
5.	Po (107)	27.29	
6.	Po (106)	26.65	

4.2 Diameter

The results of growth in diameter for the species tested were compared. Here also, three overlapping groups were apparent. The group consisting of Po (102) and Pm (111) appeared to be better in diameter growth than Pm (110), Po (095), Po (107) and Po (106). Ranking for individual species were stated below, with lines linking those that were not significantly different.

Diameter (in) 1991

Sr. No.	Species	Height	DMRT (95%)
1.	Po (102)	6.07	
2.	Pm (111)	5.81	
3.	Pm (110)	5.17	
4.	Pp (095)	4.99	
5.	Po (107)	4.71	
6.	Po (106)	4.43	

4.3 Basal area per acre

In order to assess the performance of individual species/provenances, basal area per acre was used as a criterion to find out the differences in yield among the species tested. Duncan's multiple range test indicates that in terms of basal area growth, *pinus maximinoi* (111) stands out to be significantly different from the others (see also figure 1). For simplicity, species groups which do not differ significantly are presented by a bar spanning them.

Basal area per acre (1991) (sq.ft.)

Sr. No.	Species	Height	DMRT (95%)
1.	Po (102)	92.27	
2.	Pm (111)	55.26	
3.	Pm (110)	48.05	
4.	Pp (095)	40.43	
5.	Po (107)	28.97	
6.	Po (106)	28.89	

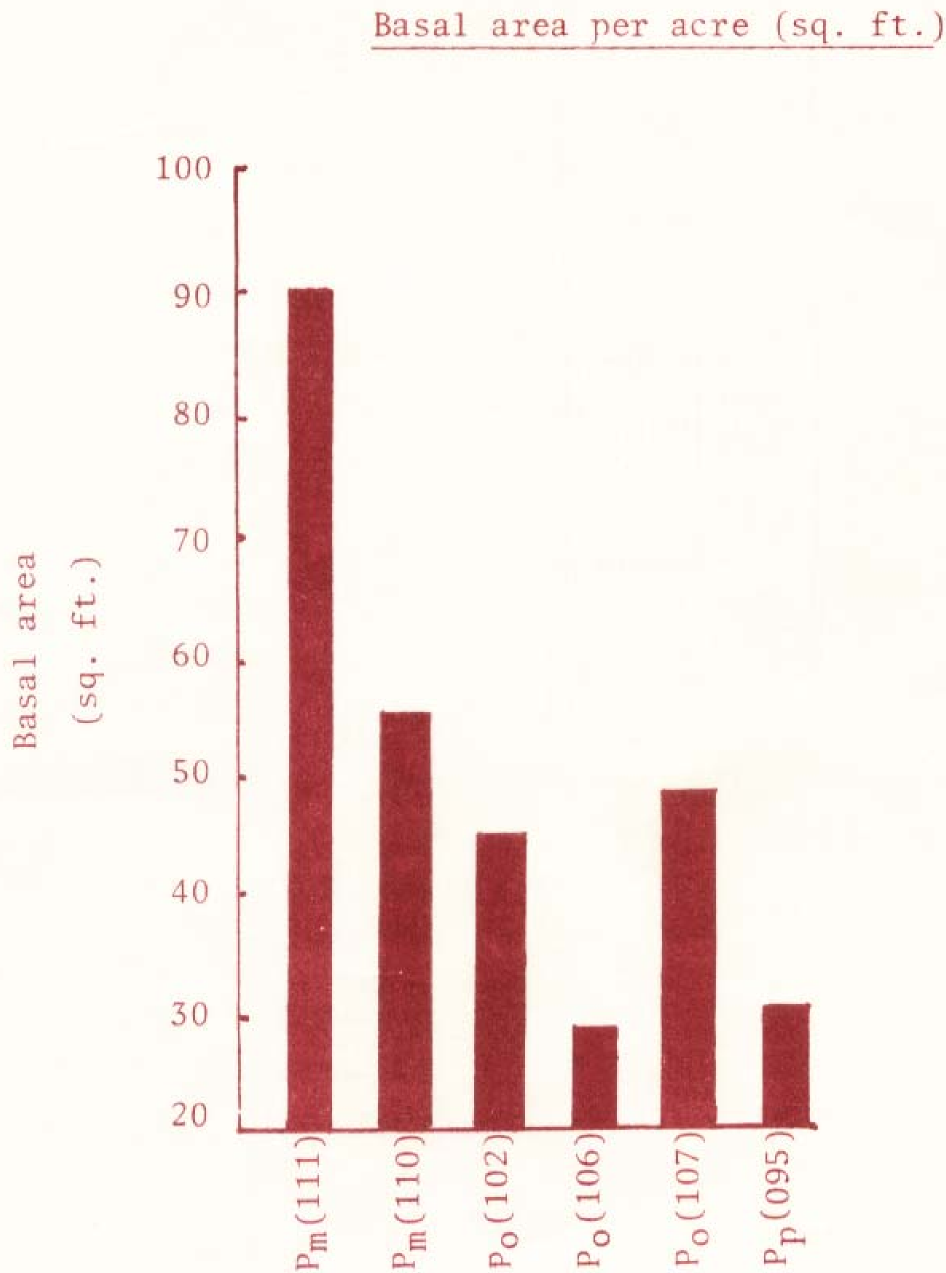


Figure 1. Basal area per acre of the tested species in 1991.

4.4 Branch characteristics

Wholes per annum figures are 2.03, 1.97, 1.87, 1.65, 1.64 and 1.44 for Po (102), Pp (095), Po (107), Pm (110), Pm (111) and Pp (106) respectively. Pp (102), Pp (095) and Po (107) therefore have two periods of shoot extension, while others are lesser on average per year.

The number of whorls per foot of stem gives a better estimate of the frequency of branches (and therefore knots) up the stem. Po (107) has most whorls per foot while Pm (111) produces the least number of whorls among the species tested.

The number of branches per whorl are fairly constant for Pm (111), Pm (110) and Pp (095) (2.50, 2.67 and 2.75 branches per whorl) but are a bit higher for Po (102), Po (106) and Po (107), having 2.91, 3.33 and 3.06 respectively.

Branch diameter of *P. oocarpa* species are much thinner than *P. maximinoi* and *P. patula* species. Pm (110) has by far the thickest branches (1.1") while Po(102) has the thinnest (0.8") among all the species tested. The total converted branches per whorl, which gives the best overall estimate of number and size of future knots per whorl are: 0.061, 0.072, 0.085, 0.096, 0.101, 1.101 for Po (102), Pm (111), Pm (110), Pp (095), Po (106), and Po (107) respectively. Po (102) therefore shows the rest, Pm (111), Pm(110) and Pp (095), intermediate between them.

Mean branch angle for the tested species are, 58.7, 79.9, 66.3, 79.8, 71.7, and 50.5 for Pm(111), Pm(110), Po(102), Po(106), Po(107), and Pp(095) respectively. Pp(095) is the species with steeper branch angle while the rest have the more desirable flatter branching.

4.5 Stem defacts

Among the species tested, the percentage of trees with basal sweep is quite low in pm (111) and Po (106) while Po (107) has the highest percent. Pm (111) also has the least trees with sinuosity, while Po (107) has the highest amount of sinuous trees. The rest lie in between them. Percentage of forking is low for Pm (111), Po (102), Po (106) and Po (107). However, Pp (095) and Pm (110) have very high percentage of forked stems. Incidence of foxtailing occur in Pm (111), Pm (110), Po (102) and Po (106), but the percentage is comparatively very low.

4.6 Fruiting and flowering

Majority of the tested species bear flowers or fruits (cones) at the age of ten. The ripe cones when examined contained well developed seeds.

5. Discussion

As stated earlier, when provenance trials on *P. kesiya* were carried out in Northern Rodesia, it was reported that *P. kesiya* from Myanmar was inferior in growth rate as well as stem form compared to other provenances in the South East Asian region. Branching characteristics was also catergorised in the worst grouping (Shelbourne, 1963).

Moreover, when *P. kesiya* from Asian and African regions were put on trial in the Northern Terrority of Australia, together with the Carribean Pine, it was quite clear that all the provenances of *P.kesiya* were inferior to the Carribean Pine (Tozer et al., 1985). Futhermore, even among the seven provenances of *P. kesiya* tested, it was reported that provenance from Myanmar was the worst.

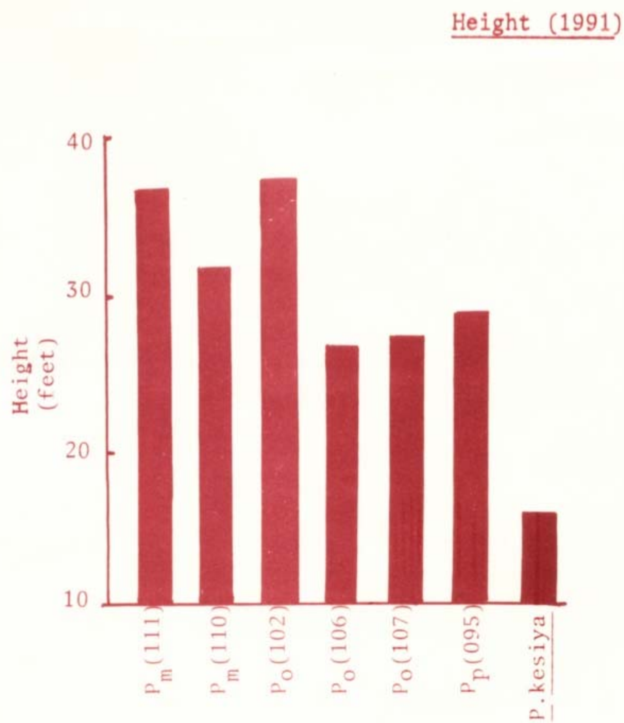
These two studies indicated the poor performance of *P. kesiya* from Myanmar. Observation on locally grown *P. kesiya* of Myanmar either in plantations or in natural stands also exhibited very poor growth and form (Gyi, et al., 1987). That is the reason why tropical pines from the Central American region were put on trial in Myanmar, so as to find out whether they perform equally well as has been reported (Greaves, 1980).

The results from the present study reveals that all the exotic pine species perform much better than the indigenous *P. kesiya* in the Shan State. Measurement data of height and diameter from locally grown *P. kesiya* of the same age and planted adjacent to the experimental plot, are distinctly inferior to those obtained from the present trail (see figure 2 and also plate 1 & 2).

In the present study, in terms of height and diameter growth, it is quite clear that Pm (111) and Po (102) appeared to be the two most promising species. However, when basal area per acre was assessed, Pm (111) outclassed Po (102), leaving Pm (111) to be the best species among all the species tested. The low basal area per acre for Po (102) stems from the low survival percent which was clearly indicative from the earlier assessment (Gyi, et.al., 1987). Po (102) gave the lowest survival percent of 67% at that time.

Generally, most species tested follows the same trend of growth as indicated during the first assessment. Pm (111) was the best in terms of both survival and growth, while Po (106) and Po (107) were not satisfactory at all during the initial assessment (Gyi, et.al., 1987). One noticeable difference was the performance of Po (095). Though it performed quite satisfactory in the earlier period, it produced very poor growth, having the lowest basal area per acre of 28.89 c. ft at the age of ten. This may probably be associated with the decline in survival percent drastically from 88% in the first year to almost 40% at percent.

Although the need for assessing stem straightness, branch size and branching habit was realized during the initial assessment, the trees at that stage were considered to be still small for such assessment at that time. Assessments on branch size, branching habit and stem form were carried out in the present study and the results presented in Table 2 and 3.



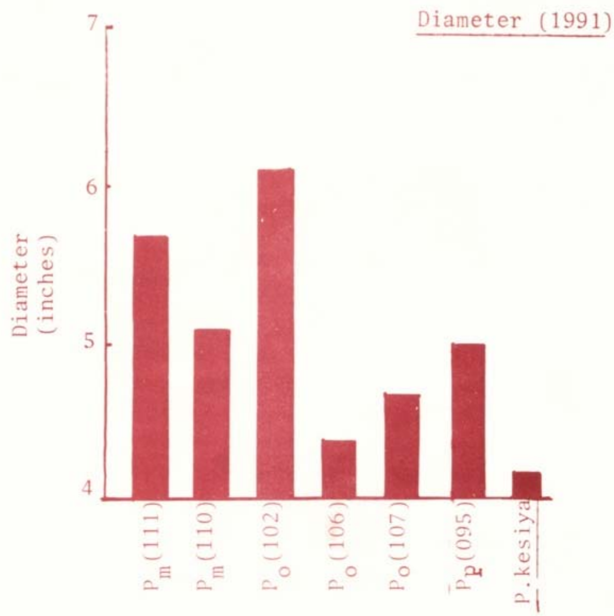


Figure 2. Comparative height and diameter growth of P.kesiya and exotic tropical pines.

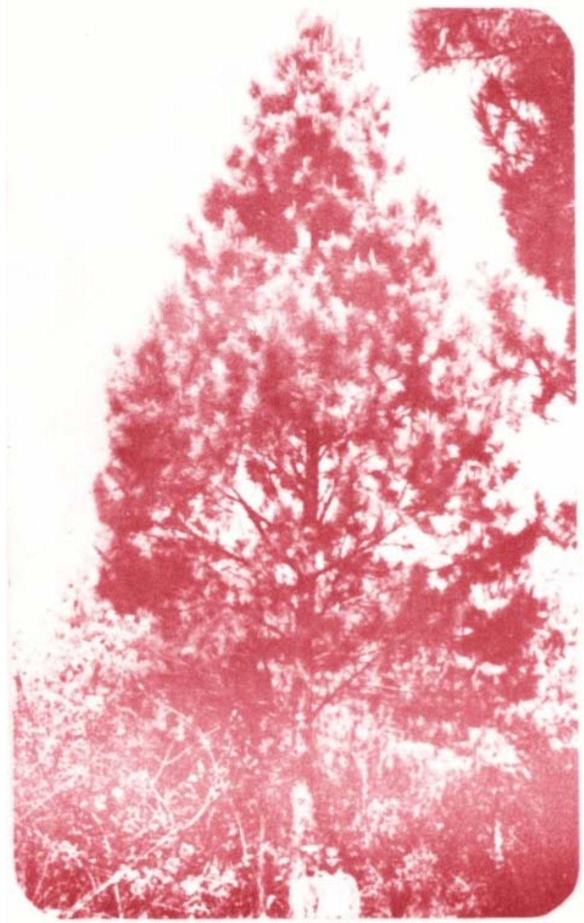
Plate 1.

Pinus maximinoi (111)

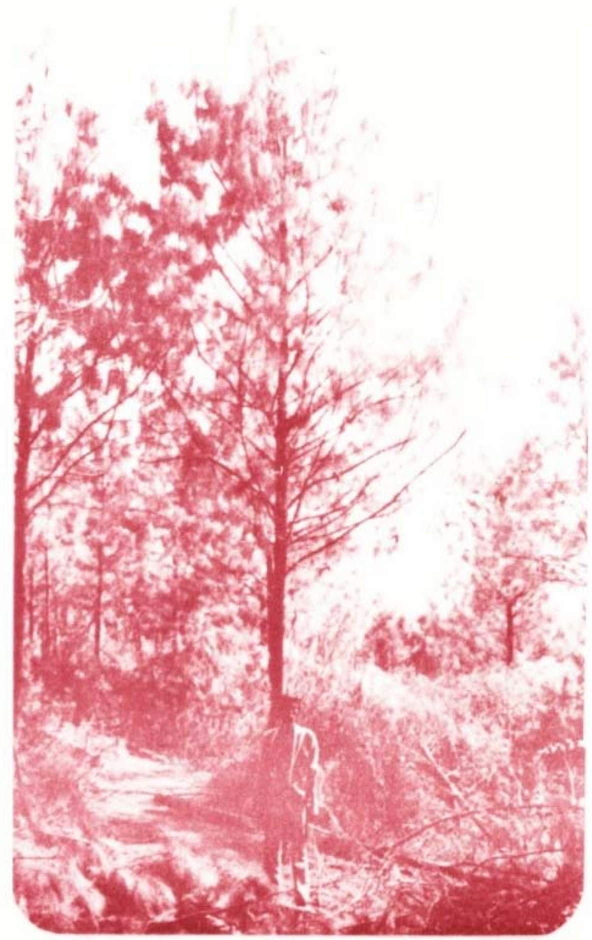
Pinus kesiya

Ten years oia tropical pines (Pinlaung junction)

Plate 2.



Pinus oocarpa (102)



Pinus patula (095)

Ten years old tropical pines (Pinlaung junction).

It will be quite interesting to compare the results of branch characteristics of some exotic pine species in this study with those from *Pinus kesiya* provenances examined in Northern Rodesia . The results of *P. kesiya* from four provenances were given by Schelbourne (1963) and is presented is tabular form below:-

Provenance	**No. of whorls per foot**	**Branch/ whorls**	**Branch dia.**	**Converted br. dia./whorl**	**Branch angle**
Benquet	0.62	4.5	0.75	0.136	63.8
Dalat	0.54	4.7	1.00	0.207	55.8
Madagascar	0.54	4.5	0.96	0.203	54.3
Assam	0.65	5.5	0.91	0.268	52.8

Among the six exotic species tried Pm (111) is the only species with the least number of whorls per foot, while the remaining five species tested and the four provenances of *P. kesiya* that was examined by Schelbourne have more or less the same number of whorls per foot. All exotic species have fewer number of branches per whorl; 2.5 to 3.3 for the exotics against 4.5 to 5.5 for *P. kesiya.* When converted branch diameter were compared, the exotics out-performed *P. kesiya* by having less amount of knots likely to have in future. The trend is almost the same for the branch angle. The exotic pines generally have flatter branches than *P. kesiya* (see plates 3 & 4).

Plate 3

Pinus maximinio (111)

Pinus kesiya

Branching habit of various tropical pine species.

Plate 4.

Pinus oocarpa (102)

Pinus patula (095)

Branching habit of various tropical pine species.

Concerning stem defects, the most serious ones which degrades the quality of timber are sinuosity, basal sweep, forking and foxtailing. Sinuosity is associated with asymmetry of cross-section creating compression wood which is deleterious. Basal sweep also generates compression wood which is therefore not desirable. Foxtailing which is an aberrant growth form is considered to be not a desirable trait. Among the species tested, Pm (111) stands out to be the only species with the least amount of defects which will degrade the timber quality.

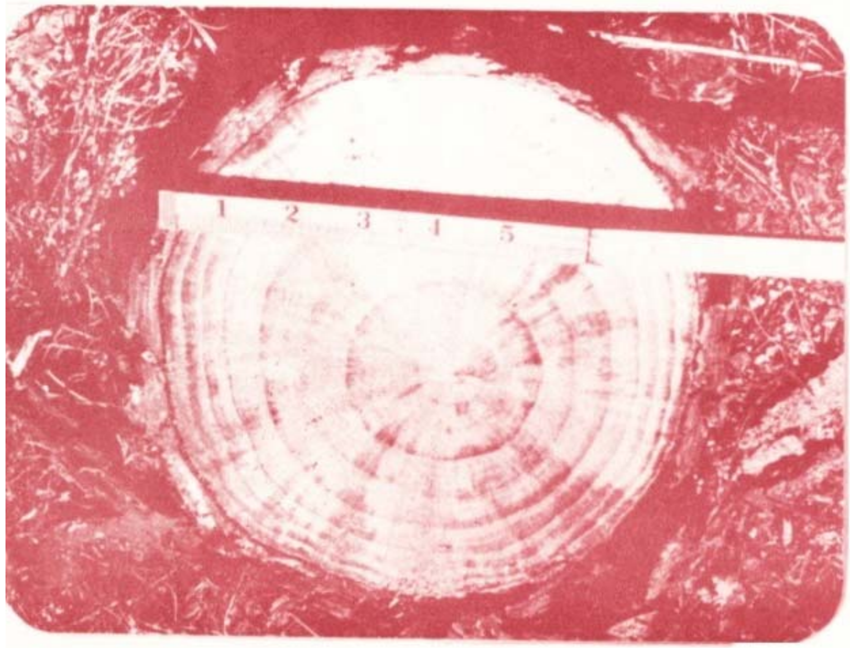
A comparative data of mean annual height increment (MAHI) and mean annual diameter increment (MADI) of the tested species, for the two assessment periods were presented in the following table:-

Species	**MAHI (ft)**		**MADI (inches)**	
	(1986)	(1991)	(1986)	(1991)
Pm (111)	3.35	3.68	0.78	0.58
Pm (110)	2.96	3.21	0.57	0.52
Po (102)	2.98	3.74	0.77	0.61
Po (106)	2.39	2.67	0.56	0.44
Po (107)	2.29	2.73	0.54	0.47
Pp (095)	3.02	2.84	0.65	0.50

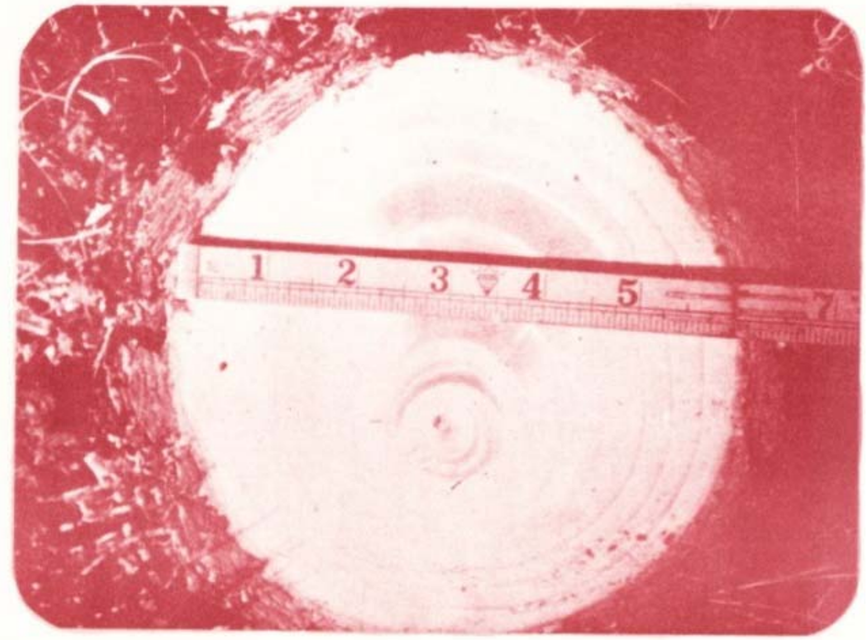
Height increment is in increasing trend for all the tested species, except Pp (095), while diameter growth declines for all tested species. The decline in diameter increment may probably be arisen from congestion of the stand, due to delay in timely thinning. This fact was fully supported by the study of growth pattern from felled stumps, that the growth rings started to congest at the age of five (see plate 5). This fact urges the need for earlier thinnings at the age of five for the proper development of the stand.

From the various aspects considered above, it is quite certain that Central American pines have more desirable characteristics than indigenous *P. Kesiya*. However, among the exotics tested, Pm (111) stands out to be the most desirable species in terms of growth as well as stem form and branching characteristics, for the production of maximum volume of straight, knot free timber with minimum conversion losses. Po (102), the species which performed very well in both height and diameter growth, despite poor survival percent, needs reexamination using a slightly bigger planting stock. Gyi *et al*., (1987) has pointed out that the planting stock used at the time of planting was too small (ie., 6" against 10" - 12" for the other species) and that may possible be the reason for low survival percent of the species during the younger stage, which drastically effects the growth production in the later stages.

Plate 5.



Pinus maximinoi (111)
Variation in annual ring growth of *Pinus maximinoi*(111). Wider growth rings formed during theearlier stages up to the fifth year and thengrowth becomes checked, due to competition.



Pinus kesiya
Variation in annual ring growth of *Pinus kesiya*. Even growth rings can be observed, which indicates competition has not yet started, probably due to slower growth.

6. Conclusion and Recommendations

1. *Pinus maximinoi* (111) from Dulce Nombre, Fonduras, shows a clear superiority, in terms of growth, stem form and branching characteristics among all the species and provenance tested. This species was also the best both in survival and growth during the early stages of development. Hence, this species is highly recommended for use in plantation establishment in the Shan State.
2. *Pinus occarpa* (106), from Pimientilla, Honduras, *P.occarpa* (107) from Pneble Viejo, Guatemala and *P.patual* (095), are not recommended for plantation establishment in the Shan State.
3. It is strongly felt that *Pinus occarpa* (102) from Yucul, Nicaragua should be put on trail again using well developed seedling, as growth and form of the species was very encouraging despite its low survival rate in the early stages.
4. With the present State of knowledge, thinnings in plantations of the species tested should be carried out at the age of five years.
5. More research studies on pruning, thinning, phenology, and investigations on wood properties should also be carried out for the proper development of tropical pine plantations in Myanmar.

Appendix 1.

Collector's No.	FRI lot no.	Country	Site	Latitude	Longitude	Altitude	Rainfall
K 104	110	Honduras	Loma de Ochoa	14˙48' N	87˙30' W	3937'	55" (April to August) Rain period
K 150	111	Honduras	Dulce Nombre	14˙52' N	88˙49' W	3937'	65.8"(1"- 3.3") Dry period)
K 42	102	Nicaragua	Yucul	12˙55' N	85˙47' W	2953'	55" (0.4"-2.6") Dry period
K 99	106	Honduras	Pimientilla	14˙54' N	87˙30' W	2133'-2789'	44.6"(0.2"-2.2") Dry period
K 111	107	Guatemala	Pueblo Viejo	15˙22' N	91˙36' W	5578'-6234'	40.8" (0"-9.4") Dry period
-	095	-- not available ---					

Appendix 2. Block-wise estimates for number, diameter, height and basal area per acre.

Block I

Sr. No	Species	N	D (in)	H (ft)	B.A/acre (sq.ft)
1.	Pm (111)	127	6.35	39.16	111.09
2.	Pm (110)	78	5.37	31.95	52.25
3.	Po (102)	54	6.41	38.34	51.20
4.	Po (106)	59	4.60	28.73	29.71
5.	Po (107)	53	5.25	30.18	60.58
6.	Pp (095)	27	5.07	27.55	15.85

Block II

Sr. No	Species	N	D (in)	H (ft)	B.A/acre (sq.ft)
1.	Pm (111)	113	5.26	34.44	73.44
2.	Pm (110)	99	4.97	32.18	57.99
3.	Po (102)	38	5.73	36.51	29.66
4.	Po (106)	66	4.25	24.57	28.23
5.	Po (107)	79	4.16	24.40	35.52
6.	Pp (095)	76	4.90	29.29	41.83

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