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Provenance trial with Pinus caribaea Morelet and P. pseudostrobus Lindl. in Orissa, India

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Summary

Results on height and diameter, mortality, foxtail, and stem form are presented from a provenance trial at Koraput, Orissa, with 8 provenances of *Pinus caribaea* var. *hondurensis*, 1 provenance of *P. caribaea* var. *bahamensis*, and 1 provenance of *P. pseudostrobus* at the age of 9 years. The two var. *hondurensis* provenances Limones (Honduras) and Santa Clara (Nicaragua) show fastest growth. Mortality of most of the provenances was high in the first year after planting and should be reduced by improved nursery and planting techniques. Foxtail frequency and stem form varied greatly between the var. *hondurensis* provenances. Some provenances had many foxtails and individuals of poor form. The var. *bahamensis* provenance from Andros Island had the least number of foxtails and excellent stem forms. The trial shows also that *P. pseudostrobus* cannot be recommended for plantations in Orissa because of a low height and diameter growth, high mortality, many foxtails, and poor stem form.

Key words: Pinus caribaea, P. pseudostrobus, height growth, diameter, mortality, foxtail, stem form.

Zusammenfassung

In einem Provenienzversuch bei Koraput, Orissa, mit 8 Herkünften von *Pinus caribaea* var. *hondurensis*, 1 Herkunft von *P. caribaea* var. *bahamensis* und 1 Herkunft von *P. pseudostrobus* wurden Höhe und Durchmesser, Mortalität, Foxtail-Häufigkeit und Stammform bis zum Alter von 9 Jahren untersucht. Bestes Wachstum zeigten die beiden var. *hondurensis*-Herkünfte aus Limones (Honduras) und Santa Clara (Nicaragua). Die Mortalität war bei den meisten Herkünften im ersten Jahr nach der Pflanzung sehr hoch. Dies kann sicherlich durch verbesserte Anzucht- und Pflanzverfahren verringert werden. Hinsichtlich der Foxtail-Häufigkeit und der Stammform bestand zwischen den var. *hondurensis*-Herkünften eine große Variationsbreite. Besonders die gutwüchsigen Herkünfte enthielten viele Foxtail-Bäume. Die geringste Foxtail-Rate und ausgezeichnete Stammform besaß die var. *bahamensis*-Herkunft Andros Island. *P. pseudostrobus* kann aufgrund geringer Wüchsigkeit, hoher Mortalität sowie vieler Foxtail-Bäume und schlechter Stammformen nicht für den weiteren Anbau in Orissa empfohlen werden.

1. Introduction

Pinus caribaea MORELET became the most important lowland timber tree species being planted in tropical countries (LAMB, 1973). It is also a promising pine species for Orissa, India (DAS, 1971, 1982). Large scale plantations with *P. caribaea* are in progress.

In Orissa the first trials with these pines were established in Kalinga Research Centre with the two varieties namely var. *caribaea* MORELET and var. *hondurensis* BARR. and GOLF. Subsequently in 1967 *Pinus caribaea* var. *bahamensis* BARR. and GOLF. was tried at Daringbadi Research Centre.

In the local environment it was noticed that *P. caribaea* var. *hondurensis* showed the best suitability. Among the various provenance trials the one from Mountain Ridge (Belize) gave the best performance in height and diameter growth. *Pinus caribaea* var. *bahamensis* exhibited good form at higher elevations around 900 m.

In subsequent field experiments in Kalinga, Daringbadi, Koraput, Pottangi and Maliput research centres various provenances of *P. caribaea* var. *hondurensis* from Belize, Guatemala, Australia, Nicaragua and Honduras were also tried with varying results (DAS, 1971, 1982). Two provenances of *P. caribaea* var. *bahamensis* (Bahamas and Andros Island) were tried in Daringbadi and Koraput Research Centre in 1967 and 1972.

For a better appreciation of the intraspecific variation of *P. caribaea* provenance trials are necessary to choose the best varieties and provenances for large scale plantation.

In the following paper results on performance, mortality and stem form are presented from a provenance trial at the research centre at Koraput, Orissa, with 9 provenances of *Pinus caribaea* and 1 provenance of *P. pseudostrobus* LINDL. at the age of 9 years.

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2. Materials and Methods

2.1. *Plant material*

The geographical data of the species and provenances, collected during 1970—71, are given in *Table 1.* An available provenance of *P. pseudostrobus* was included in the trial. The material is part of an international provenance trial organized by the Commonwealth Forestry Institute, University of Oxford, and has been supplied by the Forestry Research Institute, Dehra Dun, India. The seed lots had been sown in the beginning of November 1972 in the nursery of the Koraput Research Centre.

2.2. *Nursery technique*

2.2.1. *Preparation of seed beds and sowing*

The site for the seed is dug to a depth of 30 cm during September/October and the soil exposed to sun for about one month. The nursery beds (3 × 1 m) are prepared then and a 7.5 cm thick layer of fine granular sand is spread uniformly on the surface. 80 g of a copper fungicide (Blitox) is applied to each bed and mixed with the top layer of sand prior to the day of sowing. Generally the seeds do not require any pre-treatment. But if the individual seed lots are put in cloth bags, held in a bucket of water for 5 to 10 min until they are just wet, and then are dried, the germination percentage is better. Seeds are then mixed with Blitox powder till they are coated with a thin layer. Seeds are drilled in lines of 1 cm apart and covered with a layer of coarse sand. Soon after sowing the seed beds are mulched with paddy straw to hasten germination. Regulated watering is carried out once or twice a day.

2.2.2. *Transplanting of seedlings*

The seedlings are transplanted to polythene pots after about 30 to 45 days when they are generally 7 to 10 cm high. A mixture of sand, soil and farmyard manure is used at a ratio of 2:1:1. Each seedling is inoculated with active mycorrhiza from established stands of *Pinus caribaea.* The potted seedlings are kept under shade during the first summer.

2.3. *Field triol*

2.3.1. *Planting procedures*

Planting is generally carried out at the onset of monsoon (July/August) when the seedlings are 30 to 45 cm high. Before planting the seedlings, 45 cm^3 pits are dug and refilled with top soil mixed with gamaxene 10% (10 to 15 g) to prevent termite attack. 50 g superphosphate is applied to each seedling in two split doses (July/August). In the first year 3 weedings, in the second year 2 weedings, and in the third year one weeding followed by soil working are done.

2.3.2. *Test location*

In July 1974 the provenance trial was established with $1^1/_2$ year old potted seedlings at Koraput.

Geographical data of the location: Latitude 19.5° N, longitude 82.35° E; 850 m above sea level. Mean annual rainfall 1750 mm, which is confined to rainy season July to October only. Winter rainfall is received occasionally in December or January. The maximum and minimum temperature varies from 36° C to 5° C. Humidity varies from 89% to 62%.

The site is characterised by red lateritic bouldry soil with outcrop of rocks and with no humus.

2.3.3. *Type of forest*

Moist deciduous with moist peninsular valley Sal subtype. Due to repeated shifting cultivation the site is depleted and without satisfactory regeneration of any principal tree species like Sal (*Shorea robusta* GAERTN.) or its associates.

2.3.4. *Design*

The trial was planted in a randomised block design with 5 replications. Each plot had 5 × 3 plants at a spacing of 2.5 × 2.5 m from plant to plant and plot to plot. The spacing between the blocks was kept at 3 m.

2.3.5. *Traits measured and evaluated*

Height and mortality were measured and calculated annually in December from 1974 onwards on 35 to 66 plants. In 1975 the plant diameter above ground was measured.

Table 1. — Origin, germination, mortality and growth performance of 9-year old *Pinus caribaea* and *P. pseudostrobus* provenances in a trial at Koraput, Orissa, India.

no.	C.F.I. no.*)	origin	latitude °N	longitude °W	elevation m	seed germination %	mortality 1981 %	height 1981 m	diameter 1981 cm
Pinus caribaea var. hondurensis									
1	22/70	Nicaragua, Alamicamba	13°34'	84°17'	25	48	23	7.84	10.5
2	24/70	Honduras, Rio Coco	14°45'	83°55'	70	25	16	7.89	10.7
3	28/70	Honduras, Guanaja	16°27'	85°54'	75	75	12	7.41	11.2
4	36/71	Honduras, Limones	14°03'	86°42'	700	45	13	9.23	12.4
5	38/71	Honduras, Brus Lagoon	15°45'	84°40'	10	25	31	7.60	9.9
6	45/71	Nicaragua, Santa Clara	13°48'	86°12'	700	35	29	8.76	12.2
7	43/71	Belize, Santos	17°34'	88°33'	30	45	23	6.83	10.4
10	105	Guatemala, Poptun	16°21'	89°25'	500	20	39	6.33	8.1
						$\bar{x}$ 40	23	7.74	10.7
Pinus caribaea var. bahamensis									
8	69/7296	Bahamas, Andros Island	24°53'	78°07'	10	50	29	6.44	8.1
Pinus pseudostrobus									
9	52	Nicaragua	not known			58	53	4.77	6.3

*) Registered number of the Commonwealth Forestry Institute, Oxford.

Table 2. — Results of the analyses of variance for *Pinus caribaea* provenances at tree age of 9 years.

source of variation	d.f.	mortality 81			height 81			diameter 81		
		F-value	variance component		F-value	variance component		F-value	variance component	
			abs.	%		abs.	%		abs.	%
replications	4	2.74*	0.864	14	5.78***	1749.807	13	3.03*	0.189	6
provenances	8	2.14 n.s.	1.025	16	14.64***	8987.069	64	14.26***	2.227	68
repl.x prov. (residual)	32	-	4.481	70	-	3293.738	23	-	0.840	26

n.s. = not significant; * $\leq$ 5%; *** $\leq$ 0.1%.

The diameter measurements at 1.3 m breast height were taken from 1976. These characters were analysed as plot means according to a linear variance component model. Spearman's rank correlation coefficients were calculated between different traits on the basis of provenance means.

3. Results

3.1. *Seed germination*

Germination started within 10 to 15 days and was completed within 18 to 20 days. The germination percentages of the provenances had been evaluated 4 to 8 weeks after sowing and differed between 75% *(P. caribaea* no. 3) and 20% *(P. caribaea* no. 10) with an average of 40% in *P. caribaea* var. *hondurensis* provenances *(Table 1).*

3.2. *Mortality*

After 7 years in the field great differences exist between the two species and the provenances regarding the mortality percentage, ranging from 12% in the *P. caribaea* provenance no. 3 to 53% in *P. pseudostrobus (Table 1).* The differences were mainly affected by influences of replications and the repl. × prov. interaction, and showed no significance on the level of provenances in an analysis of variance *(Table 2).* As can be seen from *Figure 1* the most important and decisive time for survival were the first 1—2 years after planting. When the young seedlings have overcome this crucial period, the additional mortality rate remains low in the following years.

3.3. *Height growth*

Height growth differs significantly between the *P. caribaea* provenances after 7 years in the field *(Table 1* and *2).* About 64% of the observed total variance can be explained by provenance differences *(Table 2).* The fastest growing provenance no. 4 from Limones (Honduras) reached an average height of about 9.2 m, followed by another outstanding provenance no. 6 from Santa Clara (Nicaragua) with 8.7 m. The tallest trees had more than 11 m. Comparatively slow growing provenances reached an average height of about 6 to 7 m. The difference between the fastest and the slowest growing *P. caribaea* provenance is 46%. *Pinus pseudostrobus* had the lowest height growth with about 4.7 m *(Table 1).* The mean height of all provenances belonging to var. *hondurensis* is 7.7 m, which demonstrates also in this trial the generally better performance of provenances from the distribution area of this variety when compared with var. *bahamensis* provenances. In the area of the var. *hondurensis* the provenances from Honduras and Nicaragua seem to be better growing ones than the provenance no. 10 from Poptun (Guatemala).

The height growth development of the provenances during the period 1974 to 1981 is demonstrated graphically in *Figure 2.* The results of an evaluation of the annual increment of each provenance were of particular interest *(Figure 4).* From tree age 3 to 5 the mean annual increment was between 45 to 65 cm for *P. caribaea.* In 1978, when the trees became 6 years old, the increment was extra-

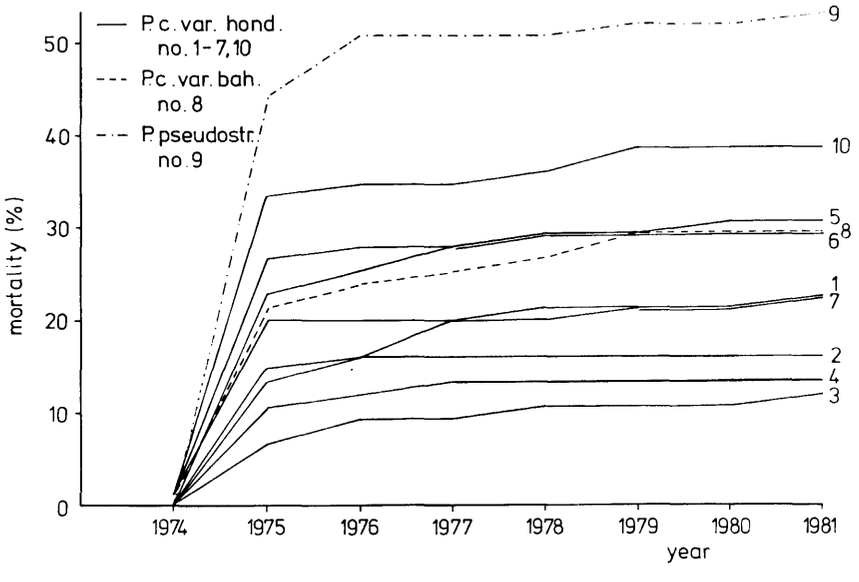

Figure 1. — Development of mortality of 9 *Pinus caribaea* and 1 *P. pseudostrobus* provenances at Koraput, Orissa.

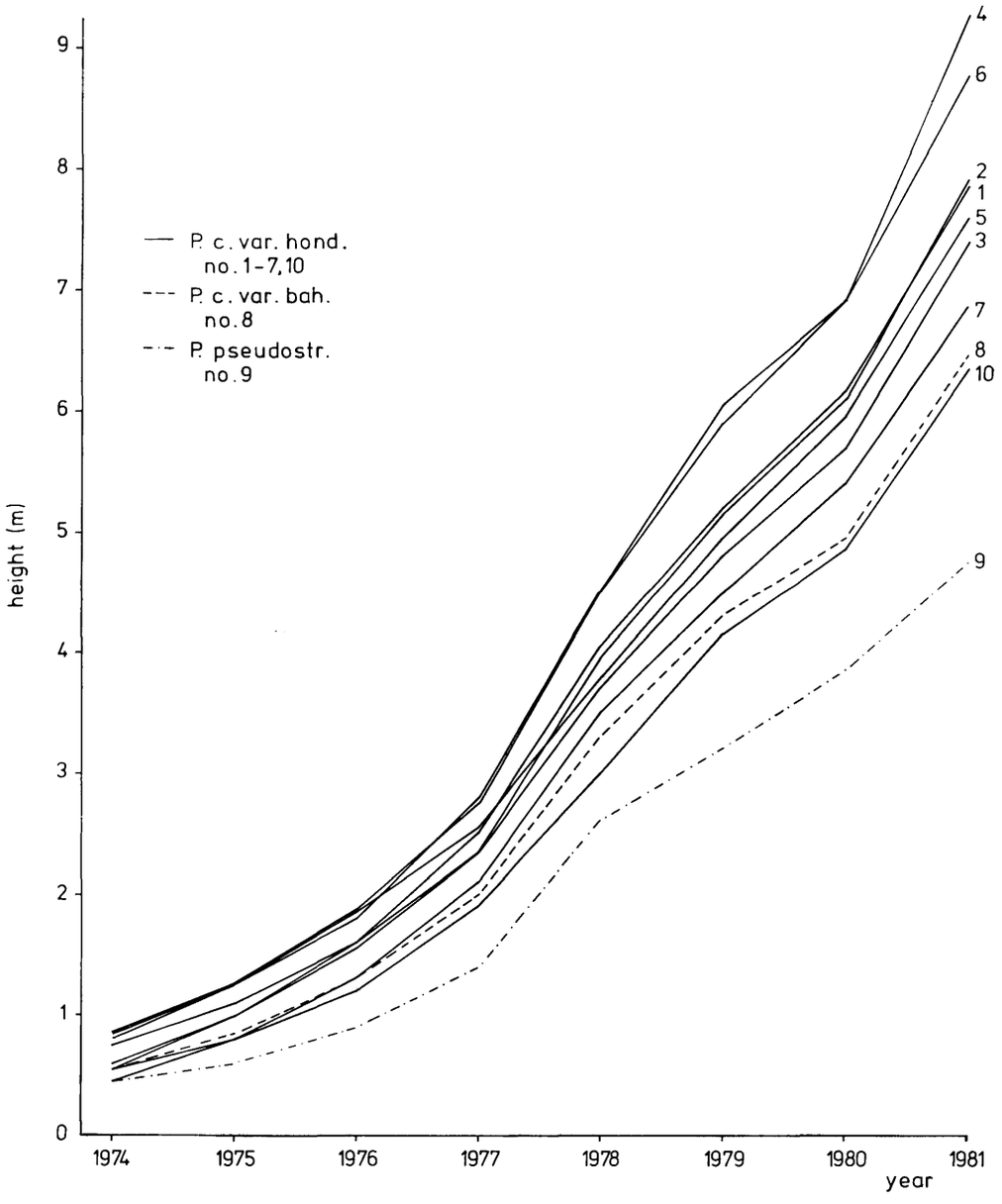

Figure 2. — Development of height growth of 9 *Pinus caribaea* and 1 *P. pseudostrobus* provenances at Koraput, Orissa.

ordinary high with values between 110 cm and 170 cm. Also in 1979 the growth was very good, decreasing in 1980 again to values similar to those in 1977. The 1981-increment again was very high with values between 140 cm and 235 cm. The mean annual increment of the 6- to 9-year old trees was calculated with 110 cm to 160 cm. All provenances showed corresponding increment curves *(Figure 4)*. *P. pseudostrobus* had in all years the lowest increment values *(Figure 4)*.

3.4. Diameter

The provenances show a similar diameter development as compared with the height growth *(Figure 3)*. The differences between *P. caribaea* provenances are significant *(Table 2)* and resulted in 68% of the total variance. Diameter values vary after 7 years in the field between 8.1 and 12.4 cm *(Table 1)* with an average of 10.7 cm for all *P. caribaea* var. *hondurensis* provenances. The differences between the provenances with the highest and the lowest diameter values is 53%. The var. *bahamensis* and the *P. pseudostrobus* provenances revealed values of only 8.1 cm and 6.3 cm respectively.

The annual diameter increment is of interest *(Figure 4)*. In the two years 1977 and 1978 the trees had the lowest increment. During this period the annual height increment showed the highest values. The highest annual increment of diameter with an average of 2.4 cm was one year later in 1979, when height increment slightly decreased. In 1980 and 1981 increments were somewhat lower with mean values of 1.5 cm and 1.7 cm respectively. The increments of height and diameter are not linear, but influenced by the environmental conditions of the respective growing season.

3.5. Correlations between various traits

The mortality rate (1981) of the *P. caribaea* provenances showed weak negative correlations with the germination percentage ($r = -0.61$; $p \leq 5\%$) and the diameter 1981 ($r = -0.67$; $p \leq 5\%$). Consequently, provenances with

good seed germination and growth seem to have less mortality.

Very high rank correlation coefficients of 0.88 to 0.98 (significance at $p \leq 0.1\%$) were obtained between the mean height of the provenances as well as between the mean diameter values for the various years. Also height and diameter were strongly correlated.

A comparison between the mean values of height and diameter and the geographical data showed strong and significant correlations with the elevations of the provenances origin ($r = 0.85$ for height 1981, and $r = 0.78$ for diameter 1981 resp.). Provenances from higher elevations seem to grow at Koraput obviously better than those from lower elevations, with exception of the provenance from Poptun (Guatemala). But because of the limited number of provenances used this observation should not be generalized. In the Koraput trial these relations are strongly influenced by the outstanding performance of the two provenances from Limones (Honduras) and Santa Clara (Nicaragua). Both originate from elevations of 700 m *(Table 1)*.

3.6. Foxtail frequency and stem form

The results of assessments of foxtail and deformity frequency are combined in *Table 3*. Foxtail trees occur in all provenances, but to a different extent. Highest percentage of foxtails with 20% could be observed in the two Honduras provenances Rio Coco and Limones, followed by another Honduras provenance Brus Lagoon, and two Nicaragua provenances from Alamicamba and Santa Clara with 15% foxtails. In *P. caribaea* var. *hondurensis* the least numbers of foxtails were found in the two provenances from Guanaja (Honduras) and from Poptun (Guatemala) with 8%. In the *P. caribaea* var. *bahamensis* provenance from Andros Island foxtails were rare with only 4%. Heavy foxtailing of 20% occurred also in the *P. pseudostrobus* provenance. With respect to the frequency of deformed trees the provenances showed also great differences and variation. The provenances Andros Island (Bahamas) and Santa Clara (Nicaragua) had the least number of deformed trees and showed excellent stem forms. Good stem forms and relatively low numbers of slightly deformed trees were observed also in the Brus Lagoon (Honduras) and the Poptun (Guatemala) provenance. On the other hand in both Honduras provenances Rio Coco and Guanaja the stem form was poor with high frequencies of moderately and heavily deformed trees. Also in *P. pseudostrobus* the stem form was poor.

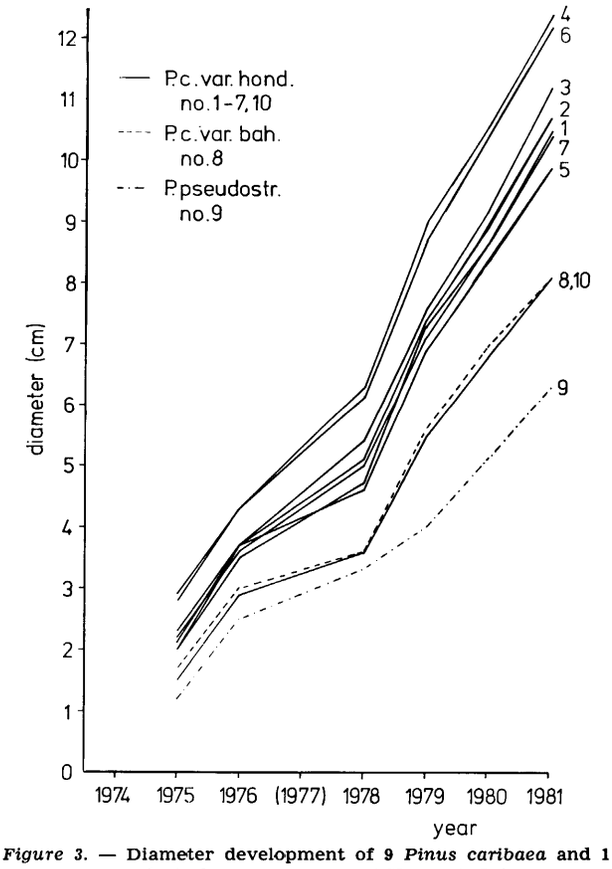

Figure 3. — Diameter development of 9 *Pinus caribaea* and 1 *P. pseudostrobus* provenances at Koraput, Orissa.

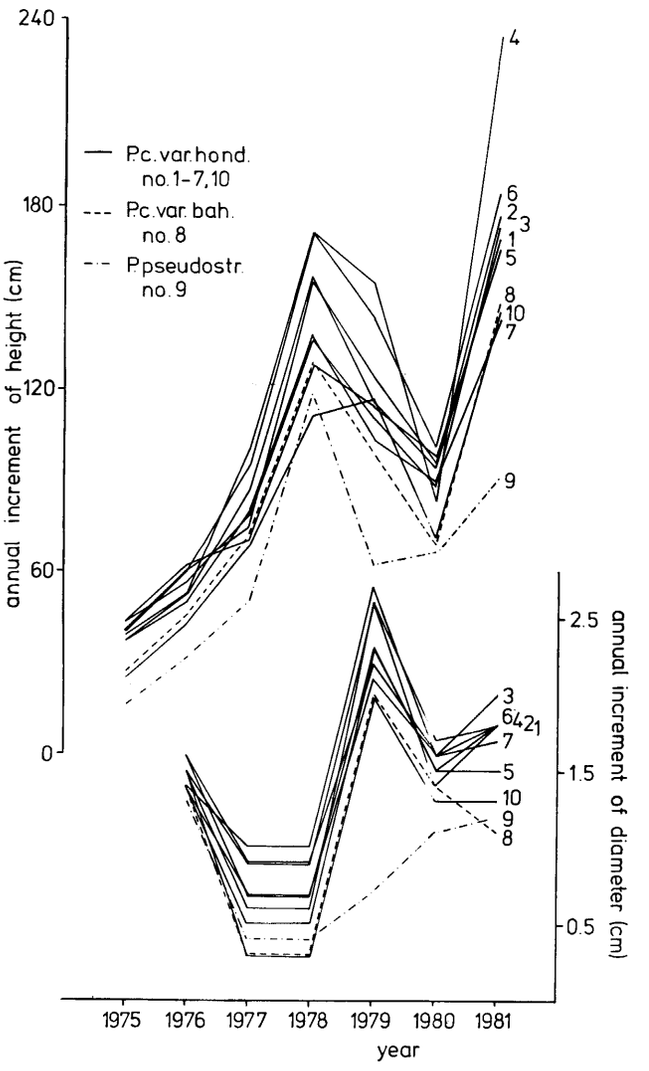

Figure 4. — Annual increment of height and diameter in 9 *Pinus caribaea* and 1 *P. pseudostrobus* provenances at Koraput, Orissa.

4. Discussion

The provenance trial at Koraput shows the known intraspecific variation of *P. caribaea* also under the environmental conditions as exist in Orissa. Among the different Central American pine species introduced in Orissa *P. caribaea* gives generally the best results. But *P. kesiya* of Philippines and of Assam (India) has given better height and diameter growth although their form is poor (Das, 1982).

The variety *hondurensis* is well suited to the local environmental conditions and for ensuring high productivity in such a barren and inhospitable area as at Koraput. Here both provenances Limones (Honduras) and Santa Clara (Nicaragua) should be preferred. At higher elevations over 900 m above sea level *P. caribaea* var. *bahamensis* may prove equal or even superior in growth as well as in form (GREAVES and KEMP, 1978), but for Orissa this has to be tested further.

It is observed that provenances of *P. caribaea* var. *hondurensis* show significant variability in stem form and branching habit, and have more defective trees than var. *bahamensis*. According to studies of LÜCKHOFF (1964) in South Africa, and SLEE and NIKLES (1968) in Australia the stem form of var. *hondurensis* is strongly modified by environmental conditions. But there seems to be also a genetic component, which makes the improvement of bole straightness possible by simple selection and breeding procedures utilizing the variation observed between and within provenances (SLEE and NIKLES, 1968).

The higher incidence of foxtail growth in var. *hondurensis* provenances has been found also by others (*e.g.* LÜCKHOFF, 1964; SLEE and NIKLES, 1968; GREAVES, 1980). Foxtails seem to be more frequent the better and longer the growing conditions are. Because of the considerable variation at the provenance and individual-tree levels an improvement by selection procedures is possible (SLEE and NIKLES 1968).

The results of growth performance and stem form in the Koraput provenance trial are in good accordance with those reported by GREAVES (1980), who reviewed the Oxford international provenance trial with *P. caribaea*. Ranking of the respective provenances according to their height growth was correlated. Generally, variety *hondurensis* provenances show higher vigour than var. *bahamensis* and var. *caribaea* provenances. But GREAVES (1980) showed that among the provenances of var. *caribaea* and var. *bahamensis* no significant growth and form differences were detected, but there were several among the var. *hondurensis* provenances. Over and above this, more provenances of *P. caribaea* var. *bahamensis* should be tried in different altitudes (about 500 m) in Orissa and their comparison with the growth of *P. caribaea* var. *hondurensis* at different altitudes should be subject matter of further studies.

The percentage of mortality has to be kept low in future not only by collection of seeds from certified sources but also by adopting improved nursery and planting techniques. This should be also a further subject of study at Koraput and Kalinga Research Centres. The nursery practice of sowing, potting, transplanting etc. influences very strongly the survival rate and vigour of the seedlings (VOORHOEVE and WEELDEREN, 1971). In this connection also the variation in drought resistance of *P. caribaea* varieties and provenances is important and should be considered (VENATOR, 1976).

This trial has also demonstrated that *P. pseudostrobus* cannot be recommended for large scale plantations in Orissa as growth performance and form were very poor. This result was not unexpected as *P. pseudostrobus* is a tree species of the Central American mountains between 1000 and 3250 m above sea level (MIROV, 1967) with very different ecological conditions.

Table 3. — Foxtail frequency and deformity of *Pinus caribaea* in the provenance trial at Koraput, Orissa.

no.	foxtails %	deformed trees % slightly deformed	moderately deformed	heavily deformed	general remarks on stem form
Pinus caribaea var. hondurensis					
1	15	10	20	0	average stem form
2	20	40	15	10	poor stem form
3	8	10	50	30	poor stem form
4	20	25	20	0	average stem form
5	15	50	0	0	good stem form
6	15	30	0	0	excellent stem form
7	12	20	40	20	average stem form
10	8	30	10	0	good stem form
Pinus caribaea var. bahamensis					
8	4	10	0	0	excellent stem form with least extent of malformity
Pinus pseudostrobus					
9	20	25	30	30	poor stem form

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