LARSON (1967) found significant differences in vegetative and wood characteristics among sources in a study of ten Pinus resinosa AIT. provenances, but uncovered no consistent relationship with geographic origin or latitude. The larger number of provenances in this present study, along with wider geographic bounds and the choice of growing-degree days to express origin, may have resulted in trends becoming apparent.

Simple correlation coefficients between growth characteristics, determined over all trees regardless of source, are included in Table 4. Because of the high degrees of freedom involved (29 provenances X 5 replicates — 2), many coefficients were statistically significant, but only those greater than 0.50 are presented. Calculation of overall coefficients is not rigorous, owing to the confounding of variation within a provenance with that among provenances. In general, however, a significant correlation among provenances was accompanied by a similarly significant r within a provenance.

As might be expected, total ring width was strongly associated with both earlywood and latewood width. Ring width also was correlated positively with total height growth and with later dates of completion of leader growth. Earlywood and latewood widths were related, and showed the same general association with height growth as total ring width. In the Petawawa material, latewood percentage was correlated with those trees having smaller percentages of their rings completed by July 15. In both experiments, latewood percentage was greater in those trees initiating latewood formation at an earlier date.


### Summary

Twenty-nine provenances were examined at two test locations for progress of wood increment formation during the 1966 growing season. Total increments and their earlywood and latewood components were consistently wider for individual provenances at the Acadia location, indicating both environmental and genotypic controls for these attributes. Wider rings, greater widths of early- and latewood, larger seedling heigths and leader lengths were associated with provenances originating from regions of greater growing-degree days. Latewood formation commenced generally at the conclusion of the grand period of leader growth. Latewood percentage was not systematically related to provenance, but showed considerable genotype-environment interaction.


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# Natural hybridization between Cuban Caribbean and Slash pines


By M. U. SLEE[1])


### Introduction

The nursery stock raised from seed collected in a plot of grafted Cuban Caribbean pine (Pinus caribaea MOR. var. caribaea B. & G.) regularly includes a proportion of seedlings differing from those typical of this species. The grafts are surrounded by Slash pine (Pinus elliottii ENGELM. var. elliottii L. & D.). Observations reported here on two batches of seedlings originating from the grafts suggest that natural hybridization has occurred between the two species.

### Material

The grafted plot contains five clones of Cuban Caribbean pine. The ortets of these clones were selected for breeding purposes in 1957 in a 24-year old trial planting of the species at Banyabba Forest in northern New South Wales, Australia (Latitude 29° 30' S.). Immediately after selection the ortets were grafted onto stock plants of Slash pine. Approximately 80 successful grafts resulted and were outplanted in 1958 at Bowenia Forest (Latitude 22° 50' S.) in central Queensland. A plantation of Slash pine, also established in 1958, surrounds the grafted plot.

Flowering of the grafts commenced in 1962 and the first seed was produced in 1964. Seedlings of Cuban Caribbean are characterized by a dark green colour, predominantly three or four secondary needles per fascicle, and the early production of secondary needles (LUCKHOFF, 1964). The first sowing of the seed from the grafts, made early in 1966, produced some seedlings which were noticeably atypical and a further sowing was made later the same year to examine this variation.

The observations reported were made on the seedlings from the later sowing, which included two batches of seed collected from the Cuban Caribbean grafts in 1965 and 1966 (Batches 65 and 66) and a control batch of Slash pine. Seedfall of Slash pine occurs in March in Queensland and it was therefore impossible to include seed collected from the Slash pine surrounding the Cuban Caribbean grafts. Seed from a routine Queensland collection was used as the Slash pine control. A Cuban Caribbean control could not be incorporated as seed was unavailable.


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## Method

The three seed batches were sown at Beerwah Forest (Latitude 26° 50' S.) in late August 1966 and gave percentage germinations from 50 to 65. The procedures followed for raising the seedlings in the nursery were as described by ROGERS (1957) for *P. caribaea*. The young seedlings were tubed in November and were ready for outplanting the following May.

Three months after sowing, an assessment of seedling variation revealed the presence of two distinct groups of seedlings within each Cuban Caribbean batch. These groups were separated at tubing, using criteria determined from the assessment and maintaining the original batch identity. The group which resembled typical Cuban Caribbean pine was designated putatively "pure Caribbean" and the other, intermediate in several characters between Cuban Caribbean and Slash pine, was designated putatively "hybrid".

A second assessment made nine months after sowing confirmed the occurrence of two distinct groups within each of the Cuban Caribbean seedling batches and provided additional information concerning the status of the putative hybrids.

*Assessment 1* (Three months after sowing)

Twenty-three or twenty-four seedlings from each of the two Cuban Caribbean seedling batches and fifty from the Slash pine control batch were selected at random. Each seedling was awarded a point score on the basis of differences in primary needle length and colour, the presence and development of secondary needles and the presence and development of basal branches immediately above the cotyledons. These branches can eventually attain a length of several inches, and are distinguishable from secondary needles by the absence of a fascicle sheath *(Figure 1)*. The scoring index awarded two points to characters typical of Slash pine, one point to intermediate characters and no points to those typical of Cuban Caribbean pine *(Table 1)*.

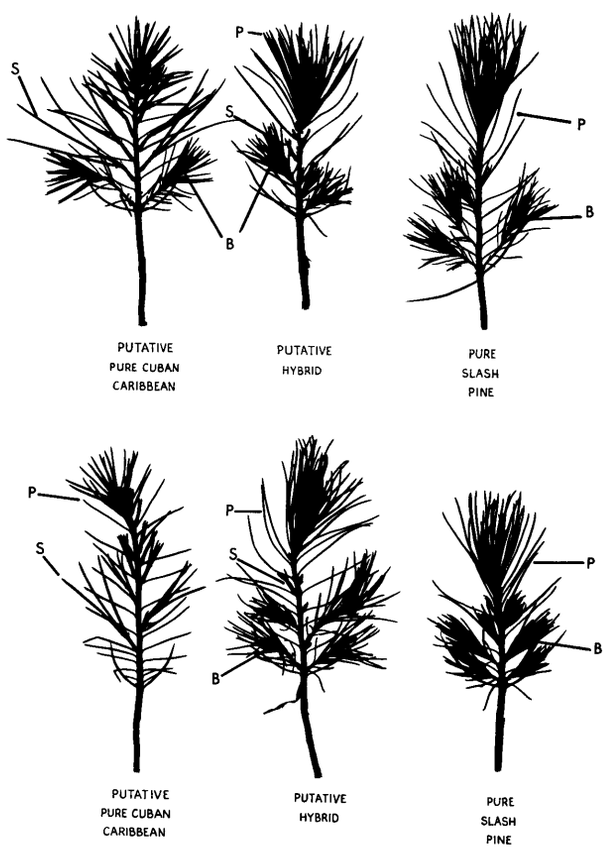


*Figure 1.* — Shadowgraphs of seedlings three months from sowing, showing the differences evident in primary needle length and in the development of secondary needles and basal branches. From left putative pure Cuban Caribbean, putative hybrids and Slash Pine. P = Primary needles, S = Secondary needles, B = Basal branches.

*Table 1.* — Details of the index used to award the point score to each seedling in Assessment 1

| Character | Variation | Score Awarded |
|---|---|---|
| Primary needle length | 0.75 in or less | 0 |
| | 1.00 | 1 |
| | 1.25 or more | 2 |
| Primary needle colour | Dark green | 0 |
| | Blue green | 2 |
| Secondary needle development | Present, emerged from sheath and elongating | 0 |
| | Present as buds only | 1 |
| | Absent | 2 |
| Basal branch development | Absent or present as one whorl only | 0 |
| | Present as two or three whorls | 1 |
| | Present as more than three whorls | 2 |

*Assessment 2* (Nine months from sowing)

Randomly selected samples from both groups of the two Cuban Caribbean seedling batches, and from the Slash pine batch were compared. The number of seedlings in each sample varied between 23 and 25 and the characters studied are detailed in *Table 2*. The three fascicles used to determine secondary needle characteristics were taken from the top of the second growth flush in the Cuban Caribbean and the putative "hybrid" seedlings and from close to the growing tip in the Slash pine. The significance of the mean differences between the two components of each Caribbean seedling batch were determined by t-tests.

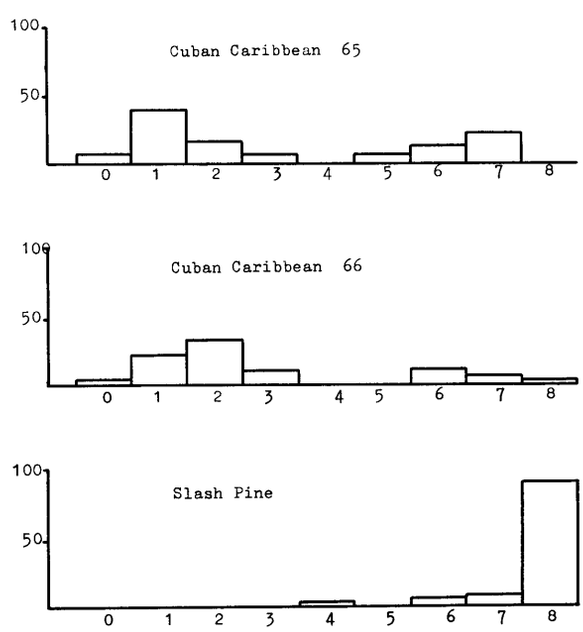


*Figure 2.* — The frequency distribution, in percentage form, of the index score resulting from Assessment 1 within individual batches (% of trees with each index score).

*Table 2.* — The characters examined in Assessment 2 with the method of study used for each

| Character | Method of Study |
|---|---|
| Total height | Measure |
| Height to the lowest secondary needle | Measure |
| Secondary needle length | Mean of three fascicles per seedling |
| Fascicle sheath length | Mean of three fascicles per seedling |
| No. secondary needles per fascicle | Count three fascicles per seedling |

## Results

The distribution of the index scores from Assessment 1 indicated two distinct groups within each of the Caribbean seedling batches *(Figure 2)*. The putative "pure Cuban Caribbean" scored a maximum of five points and the putative "hybrids" six to seven points, whilst Slash pine generally scored eight points. Thus the putative "hybrids" had characters intermediate between the putative pure Cuban Caribbean and the Slash pine.

When the complete Caribbean batches were divided into the two groups at tubing, approximately one third of the total seedlings in each batch were classified as putatively "hybrid" *(Table 3)*.

Assessment 2 verified the existence of the two distinct groups within the Caribbean seedling batches. Highly significant differences were recorded between the groups within each batch for all measured characters, except total height within Batch 66 *(Tables 4 and 5)* and differences were also found in the occurrence of four-needled fascicles *(Table 6)*.

In Assessment 2 the putative "hybrids" were only clearly intermediate between the putative "pure Cuban Caribbean" and the Slash pine in fascicle sheath length, but in other characters they either resembled Cuban Caribbean or Slash pine. For example, the height to the first secondary needle is greater in Slash than in Cuban Caribbean pine *(Table 4, Figure 1)* and the putative "hybrids" closely approximated Caribbean in this character *(Table 4)*. In contrast, the putative "hybrids" resembled Slash pine in having a very low frequency of four-needled fascicles *(Table 6)*.

*Table 3.* — Showing the numbers of seedlings in each Cuban Caribbean batch placed in the putatively pure and putatively „hybrid" group at tubing

| Seedling batch | Total number of stems | Number of stems putatively designated:— Pure | Hybrid |
|---|---|---|---|
| 65 | 102 | 65(64%) | 37(36%) |
| 66 | 95 | 64(67%) | 31(33%) |

*Table 4.* — Mean data, in inches, for all measures recorded in Assessment 2.

| Seedling batch | Group (1) | Mean height | Secondary needle height (2) | Secondary needle length | Fascicle sheath lenght |
|---|---|---|---|---|---|
| 65 | C | 4.9 | 0.83 | 5.1 | 0.26 |
| 66 | C | 6.2 | 0.79 | 5.3 | 0.26 |
| 65 | H | 6.7 | 1.04 | 6.7 | 0.34 |
| 66 | H | 6.7 | 0.98 | 6.6 | 0.32 |
| Slash | — | 10.4 | 3.30 | 5.3 | 0.40 |

(1) C = Putatively pure Caribbean
H = Putatively hybrid
(2) Height to the lowest secondary needle

*Table 5.* — The significance of the differences evident between the components of the Caribbean seedling batches as determined by t-tests on the data recorded in Assessment 2.

| Seedling batch | Significance [1]) of the differences present in:— Mean height | secondary needle height [2]) | secondary needle length | Fascicle sheath length |
|---|---|---|---|---|
| 65 | *** | *** | *** | *** |
| 66 | NS | *** | ** | *** |

[1]) NS indicates not significant at the 5% level of probability. ** and *** indicate significance at the 1% and 0.1% levels of probability, respectively.
[2]) Height to the lowest secondary needle.

*Table 6.* — The distribution of the numbers of needles per fascicle in the fascicles sampled in Assessment 2.

| Seedling batch | Group [1]) | No. fascicles counted | % of fascicles with the indicated number of needles 2 | 3 | 4 |
|---|---|---|---|---|---|
| 65 | C | 69 | — | 83 | 17 |
| 66 | C | 75 | 3 | 71 | 26 |
| 65 | H | 69 | 16 | 81 | 3 |
| 66 | H | 75 | 1 | 99 | — |
| Slash | — | 75 | 5 | 92 | 3 |

[1]) C = Putatively pure Caribbean
H = Putatively hybrid

The secondary needle length of the putative "hybrids" was significantly greater than that of the parent species *(Table 4)*. However, secondary needle development is incomplete in seedlings of this age. Fully developed needles of Cuban Caribbean pine range in length from six to ten inches (15 to 25 cm) (BARRETT and GOLFARI, 1962 and of Slash pine from six to twelve inches (15 to 31 cm) (SQUILLACE, 1966). consequently differences in needle length will not necessarily be exhibited at a later stage.

## Discussion

Two distinct groups exist within two seedling populations originating from the plot of Cuban Caribbean grafts. One group, regarded as "pure Cuban Caribbean pine", conforms to the general description of this pine as detailed by BARRETT and GOLFARI (1962) and LUCKHOFF (1964). The seedlings are slow growing, bright green, produce secondary needles very early and contain several four-needled and only very few two-needled fascicles. The other group differs from typical Cuban Caribbean pine. In the number of secondary needles per fascicle it resembles Slash pine; in primary needle colour, the production of basal branches and in fascicle sheath length it is intermediate between Slash and Caribbean pines and in the height at which secondary needles are produced on the stem it resembles, but still differs from, Caribbean pine.

Seedling characteristics of *Pinus caribaea* and *Pinus elliottii* are taxonomically reliable. They have been used by LUCKHOFF (1964) as the basis of a key to distinguish the three varieties of *Pinus caribaea* (namely var. *caribaea*, var. *hondurensis* and var. *bahamensis)*, and similarly by LITTLE and DORMAN (1954) to differentiate between the two varieties (var. *elliottii* and var. *densa)* of *Pinus elliottii*. NIKLES (1966) found four-month old seedlings of *Pinus elliottii* var. *elliottii* to differ significantly from comparable seedlings of *Pinus caribaea* var. *bahamensis* in the production of secondary needles and in needle length. NIKLES also noted that combinations of seedling characters including foliage colour, the presence of basal shoots and the occurrence of secondary needles provided a reliable method of differentiating between all five varieties of the two species.

The results of the study therefore suggest that natural hybridization has occurred between Cuban Caribbean and Slash pines. Approximately one third of the viable seed currently produced by the Cuban Caribbean grafts is probably hybrid *(Table 3)*.

Additional support for natural hybridization has been obtained from phenological studies and artificial pollinations. Both species flower at the same time (SLEE and NIKLES, 1968), and controlled pollinations between the Cuban Caribbean grafts and Slash pine have given some excellent seedsets with over 100 viable seeds per cone (SLEE, 1968).

Natural crossing of Cuban Caribbean and Slash pines suggests the taxonomy of the Slash-Caribbean complex of species may need some revision. Cuban Caribbean may hybridize naturally with Slash pine but the Honduras variety of Caribbean pine (var. *hondurensis)* will not cross readily with either (NIKLES, 1964; SLEE, 1968). The specific relationships within the complex have thus become confused. This supports the findings of BARRETT and GOLFARI (1962), LUCKHOFF (1964), NIKLES (1966) and MIROV (1967), all of whom anticipated further taxonomic changes within the complex of the two species.


## Acknowledgements

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## Summary

Two batches of seedlings originating from a plot of grafts of *Pinus caribaea* MOR. var. *caribaea* B. & G. surrounded by *Pinus elliottii* ENGELM. var. *elliottii* L. & D. are compared. Primary needle colour, time and height of secondary needle production, incidence of basal branching, secondary needle length, fascicle sheath length and needle number per fascicle indicate natural hybridization of these two species.


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