

This document has been digitised by the Bodleian Libraries, University of Oxford as part of the Oxford Digital Library for Forestry (ODLF) project.

Digitisation of this document has been made possible through the support of the Andrew W. Mellon Foundation.

The original contents of this document remain the copyright of the University of Oxford (<http://www.ox.ac.uk/>).

For enquiries please contact: enquiries.rsl@bodleian.ox.ac.uk



Provenance Variation in *Pinus caribaea*, *P. oocarpa* and *P. patula* ssp. *tecunumanii*



J.S. Birks and R.D. Barnes

PHOTOGRAPHS

Front Cover

Pinus caribaea var. *hondurensis* on Guanaja Island, Honduras. This provenance produced the best combination of growth rate and wood density across localities and differed in many traits from coastal provenances from the mainland seen on the horizon in the background.

Back Cover — clockwise from top left

Seedlings for international provenance trial of Central American pines being raised in the Mukandi Nursery in Zimbabwe.

Pinus oocarpa/*P. patula* ssp. *tecunumanii* provenance trial at Three-ways, Melville Island, N.T., Australia, showing marked difference in branching characteristics of Mountain Pine Ridge, Belize (left), and Yucul, Nicaragua (right), at six years.

Ten-year-old selection in Mountain Pine Ridge (Belize) provenance of *Pinus caribaea* var. *hondurensis* at Jari, Brazil.

Pinus caribaea var. *hondurensis* of Mountain Pine Ridge, Belize, origin showing unimproved (left) and improved by selection in Queensland (right) seed sources at seven years in Fiji.

Photographs R.D.B

Oxford Forestry Institute
South Parks Road
Oxford OX1 3RB

Telephone: (0865) 275000
Telex: 83147 VIAOR G ATTN FOROX
Fax: (0865) 275074



TROPICAL FORESTRY PAPERS
No. 21

Provenance Variation
in
Pinus caribaea, P. oocarpa
and
P. patula ssp. tecunumanii

J. S. Birks and R. D. Barnes

Oxford Forestry Institute
Department of Plant Sciences
University of Oxford
1990

ISBN 0 85074 116 5
ISSN 0141-9668

Printed and bound in Great Britain by Burgess & Son (Abingdon) Ltd, Thames View, Abingdon, Oxfordshire

Contents

	Page
PREFACE	vi
ACKNOWLEDGEMENTS	vi
SUMMARY	vii
1. INTRODUCTION	1
2. THE PROVENANCES	2
3. THE TRIALS	8
4. TRAITS ASSESSED	8
5. STATISTICAL ANALYSIS	9
5.1 Form of the data	9
5.2 Experimental design and analysis	9
5.3 Genotype-environment interaction	12
6. RESULTS	12
7. DISCUSSION	31
7.1 Provenance representation	31
<i>P. caribaea</i>	31
<i>P. oocarpa</i>	31
<i>P. patula</i> ssp. <i>tecunumanii</i>	31
7.2 Trial site coverage	32
7.3 Provenance variation	32
<i>P. caribaea</i>	32
Productivity	32
Stem quality	33
Branching	33
Reproduction	33
Wood density	34
Turpentine composition	34
<i>P. oocarpa</i> and <i>P. patula</i> ssp. <i>tecunumanii</i>	34
Productivity	34
Stem quality	35
Branching	35
Reproduction	35
Wood density	35
Turpentine composition	35
8. CONCLUSIONS AND RECOMMENDATIONS	36
8.1 Provenance variation	36
<i>P. caribaea</i>	36
<i>P. oocarpa</i> and <i>P. patula</i> ssp. <i>tecunumanii</i>	36
8.2 Provenance-environment interaction	37
8.3 Species-environment interaction	37
8.4 Future genetic development	38
REFERENCES	39

Tables and maps

	Page
Table 1	
1 Details of <i>Pinus caribaea</i> provenances used in the international trials – (Greaves, 1978).	5
2 Details of <i>Pinus oocarpa</i> and <i>P. patula</i> ssp. <i>tecunumanii</i> provenances used in the international trials – (Greaves, 1979).	7
3 Details of <i>Pinus caribaea</i> international provenance trials.	11
4 Details of <i>Pinus oocarpa</i> / <i>P. patula</i> ssp. <i>tecunumanii</i> international provenance trials.	11
5 Provenance-locality mean percentage survival for 25 provenances of <i>Pinus caribaea</i> at 16 localities.	13
6 Provenance-locality mean tree values of height (m) for 25 provenances of <i>Pinus caribaea</i> at 16 localities.	13
7 Provenance-locality mean tree values of breast height diameter over bark (cm) for 25 provenances of <i>Pinus caribaea</i> at 16 localities.	14
8 Provenance-locality mean tree value of bark thickness (mm) for 25 provenances of <i>Pinus caribaea</i> at 16 localities.	14
9 Provenance-locality mean tree volume under bark (dm ³) for 25 provenances of <i>Pinus caribaea</i> at 14 localities.	15
10 Provenance-locality mean tree values of bark proportion (%) of total tree volume (over bark) for 25 provenances of <i>Pinus caribaea</i> at 14 localities.	15
11 Provenance-locality mean tree stem straightness (index) for 25 provenances of <i>Pinus caribaea</i> at 15 localities.	16
12 Provenance-locality mean percentage of trees with stem lean greater than 2.5° for 25 provenances of <i>Pinus caribaea</i> at 16 localities.	16
13 Provenance-locality mean percentage of trees with forks or multiple stems for 25 provenances of <i>Pinus caribaea</i> at 16 localities.	17
14 Provenance-locality mean tree values of the mean number of branches per whorl for 25 provenances of <i>Pinus caribaea</i> at 16 localities.	17
15 Provenance-locality mean tree value of number of whorls (between 1 m and 6 m above ground) for 25 provenances of <i>Pinus caribaea</i> at 16 localities.	18
16 Provenance-locality mean tree value of longest internode length (m) for 25 provenances of <i>Pinus caribaea</i> at 16 localities.	18
17 Provenance-locality mean percentage of trees with fine or fine/medium branches for 25 provenances of <i>Pinus caribaea</i> at 16 localities.	19
18 Provenance-locality mean percentage of trees with cones for 25 provenances of <i>Pinus caribaea</i> at 13 localities.	19
19 Provenance-locality mean tree pilodyn reading (mm) for 25 provenances of <i>Pinus caribaea</i> at 5 localities.	20
20 Provenance-locality mean tree basic density (g cm ⁻³) for 25 provenances of <i>Pinus caribaea</i> at 13 localities.	20
21 Provenance-locality mean percentage of trees with α -pinene + β -pinene > 80% for 25 provenances of <i>Pinus caribaea</i> at three localities.	21
22 Provenance-locality mean tree log ratio of (α -pinene + β -pinene + β -phellandrene) to Δ -3-carene for 25 provenances of <i>Pinus caribaea</i> at three localities.	21
23 Provenance-locality mean percentage survival for 24 provenances of <i>Pinus oocarpa</i> / <i>P. patula</i> ssp. <i>tecunumanii</i> at 13 localities.	22
24 Provenance-locality mean tree height (m) for 24 provenances of <i>Pinus oocarpa</i> / <i>P. patula</i> ssp. <i>tecunumanii</i> at 13 localities.	22
25 Provenance-locality mean tree diameter (cm) for 24 provenances of <i>Pinus oocarpa</i> / <i>P. patula</i> ssp. <i>tecunumanii</i> at 13 localities.	23
26 Provenance-locality mean tree volume under bark (dm ³) for 24 provenances of <i>Pinus oocarpa</i> / <i>P. patula</i> ssp. <i>tecunumanii</i> at 13 localities.	23
27 Provenance-locality mean tree bark thickness (mm) for 24 provenances of <i>Pinus oocarpa</i> / <i>P. patula</i> ssp. <i>tecunumanii</i> at 13 localities.	24
28 Provenance-locality mean tree bark proportion (%) of total tree volume over bark for 24 provenances of <i>Pinus oocarpa</i> / <i>P. patula</i> ssp. <i>tecunumanii</i> at 13 localities.	24
29 Provenance-locality mean tree stem form (index) for 24 provenances of <i>Pinus oocarpa</i> / <i>P. patula</i> ssp. <i>tecunumanii</i> at 12 localities.	25
30 Provenance-locality mean percentage of trees with stem lean greater than 2.5° for 24 provenances of <i>Pinus oocarpa</i> / <i>P. patula</i> ssp. <i>tecunumanii</i> at 13 localities.	25

31	Provenance-locality mean percentage of trees with forks or multiple stems for 24 provenances of <i>Pinus oocarpa</i> / <i>P. patula</i> ssp. <i>tecunumanii</i> at 13 localities.	26
32	Provenance-locality mean tree values of the mean number of branches per whorl for 24 provenances of <i>Pinus oocarpa</i> / <i>P. patula</i> ssp. <i>tecunumanii</i> at 13 localities.	26
33	Provenance-locality mean tree value of number of whorls (between 1 m and 6 m above ground) for 24 provenances of <i>Pinus oocarpa</i> / <i>P. patula</i> ssp. <i>tecunumanii</i> at 13 localities.	27
34	Provenance-locality mean tree value of longest internode length (m) for 24 provenances of <i>Pinus oocarpa</i> / <i>P. patula</i> ssp. <i>tecunumanii</i> at 13 localities.	27
35	Provenance-locality value of the percentage of trees with fine or medium/fine branches for 24 provenances of <i>Pinus oocarpa</i> / <i>P. patula</i> ssp. <i>tecunumanii</i> at 13 localities.	28
36	Provenance-locality mean percentage of trees with cones for 24 provenances of <i>Pinus oocarpa</i> / <i>P. patula</i> ssp. <i>tecunumanii</i> at 13 localities.	28
37	Provenance-locality mean tree pilodyn reading (mm) for 23 provenances of <i>Pinus oocarpa</i> / <i>P. patula</i> ssp. <i>tecunumanii</i> at 5 localities.	29
38	Provenance-locality mean tree basic density (g cm ⁻³) for 24 provenances of <i>Pinus oocarpa</i> / <i>P. patula</i> ssp. <i>tecunumanii</i> at 11 localities.	29
39	Provenance-locality mean percentage of trees with α -pinene + β -pinene > 80% for 21 provenances of <i>Pinus oocarpa</i> / <i>P. patula</i> ssp. <i>tecunumanii</i> at three localities.	30
40	Provenance-locality mean tree log ratio of α -pinene + β -pinene + β -phellandrene to Δ -3-carene for 21 provenances of <i>Pinus oocarpa</i> / <i>P. patula</i> ssp. <i>tecunumanii</i> at three localities.	30
41	Temperature and rainfall requirements for <i>Pinus caribaea</i> vars. <i>hondurensis</i> , <i>bahamensis</i> and <i>caribaea</i> , <i>P. oocarpa</i> and <i>P. patula</i> ssp. <i>tecunumanii</i> .	37
Map 1	Natural distribution of <i>Pinus caribaea</i>	2
Map 2	Natural distribution of <i>Pinus oocarpa</i>	3
Map 3	Natural distribution of <i>Pinus patula</i> ssp. <i>tecunumanii</i>	3
Map 4	Location of <i>Pinus caribaea</i> var. <i>hondurensis</i> provenance seed collections.	4
Map 5	Location of <i>Pinus oocarpa</i> and <i>P. patula</i> ssp. <i>tecunumanii</i> provenance seed collections.	6
Map 6	Provenance trial locations.	10

Preface

For thirty years the Oxford Forestry Institute has conducted the classic stages of genetic resources exploration, evaluation, conservation and utilization of many tropical tree species. These have included conifers, fine hardwoods, arid zone multipurpose species and latterly African *Acacia* species. The exploration stage has involved intensive collection throughout the natural range of a given species while the evaluation stage has entailed field provenance trials in many countries and sites. The whole programme is one of the best examples of the benefits of collaborative network research.

This report includes the analysis and summary of results of the major international series of provenance trials of three major pine species from Central America grown on sixteen sites (*Pinus caribaea*) and thirteen sites (*P. oocarpa* and *P. patula* ssp. *tecunumanii*). These three species are the most commonly used and promising species for industrial timber, pulp and resin plantations on a wide range of tropical site conditions. The extent of provenance variation and site specificity are so great that each grower should evaluate the information for his or her own decision-making and this report provides the basic material and interpretation to facilitate such decisions.

Acknowledgements

This work would not have been possible without the cooperation and assistance of the forest authorities in Central America and the Caribbean countries where *Pinus caribaea*, *P. oocarpa*, and *P. patula* ssp. *tecunumanii* are indigenous, and of the departments, organizations, institutes and companies in countries where the provenance trials were planted. The authors and the Oxford Forestry Institute express their thanks to the many colleagues who helped at all stages of the programme. The Overseas Development Administration of the British Government has been the principal contributor of financial resources, principally through the funding of Research Schemes at the Oxford Forestry Institute for field study, seed collection and distribution, and trial evaluation. FAO also contributed funds for seed acquisition.

The great contribution of George Gibson in measuring every trial is acknowledged; he has been the author of many papers on the analysis of various parts of the data.

Dr Brian Styles has generously allowed us to use his extensive herbarium data to produce the species distribution maps.

J. Burley, K.J. Crockford, C.E. Hughes, P.J. Kanowski, and R.L. Willan kindly reviewed the manuscript and made many useful suggestions most of which we have included in the final text.

Summary

An international study of provenance variation in *Pinus caribaea* Morelet and *P. oocarpa* Schiede in Central America and the Caribbean started in the early 1960s. By the early 1970s seed had been distributed to over fifty countries for many hundreds of trials. By the late 1970s the most comprehensive of these had reached seven years, the optimum age for evaluation. A coordinated assessment programme was undertaken in a set of 29 trials in which 25 *P. caribaea* and 20 *P. oocarpa* provenances were represented. Four of the *P. oocarpa* sources were later recognized as *P. patula* Schiede & Deppe ssp. *tecunumanii* (Equiluz & Perry) Styles. Provenance representation was comprehensive for *P. caribaea* vars. *hondurensis* Barr. & Golf. and *caribaea*, except for the omission of a few isolated populations; only one var. *bahamensis* Barr. & Golf. provenance was included. Representation was satisfactory for *P. oocarpa* in Central America, but none of the populations in the central part of the range of *P. patula* ssp. *tecunumanii* in Honduras and Guatemala was sampled. New international trials of both *P. caribaea* var. *bahamensis* and *P. patula* ssp. *tecunumanii* are now in progress. Overall test site coverage was good except for *P. caribaea* vars. *bahamensis* and *caribaea*.

Eighteen traits were assessed to describe productivity, stem quality, branching, reproduction, wood density and oleoresin composition. These are summarized in provenance-locality tables. Analysis of the data revealed statistically and operationally significant general differences between provenance regions for all three species as well as local differences between provenances within the regions. Five major groups emerged in *P. caribaea*, viz. var. *caribaea*, var. *bahamensis*, and inland, coastal and insular var. *hondurensis*. Each had productivity and silvicultural attributes that were in themselves of sufficient economic importance to influence choice for operational use in different sets of circumstances. Four provenance regions could be distinguished for *P. oocarpa*, the Mexican, North Guatemalan, South Guatemalan and Honduras-Nicaraguan. The Mexican type had poor productivity and undesirable silvicultural features but the differences between the other three were in traits that had little or no immediate operational significance. The four *P. patula* ssp. *tecunumanii* provenances separated on branching traits and resin composition into a group of the three Nicaraguan populations and the one from Belize. Although genotype-environment interaction effects were not statistically estimated here, there were indications that they exist at the provenance region level for the three varieties of *P. caribaea* particularly where wind and biotic effects are significant factors in the environment. These trials have provided data that can be utilized not only to make immediate operational gains through provenance selection, but also to plan breeding strategies to enhance populations and to create synthetic varieties in a systematic genetic development for each species.

1. Introduction

In response to a request from the Eighth Commonwealth Forestry Conference in 1962, the Commonwealth Forestry Institute in Oxford, now the Oxford Forestry Institute (OFI), undertook to take a lead in the study of variation across the natural range of *P. caribaea* Morelet in Central America and the Caribbean, and to collect and distribute seed for international provenance trials. *P. caribaea* var. *hondurensis* Barr. & Golf. merges, possibly hybridizing with (Styles *et al.*, 1982; Fernandez de la Reguera *et al.*, 1986 and 1988) *P. oocarpa* Schiede, by which it is then replaced as altitude increases throughout Central America (Loock, 1950; Luckhoff, 1964). Soon after field work started, it was realized that this species also had high potential for plantation development in tropical countries. *P. oocarpa* was therefore included in the programme and seed of both species became available for testing in the mid 1960s. By the end of the 1970s many hundreds of trials had been established with representation of 20 to 30 provenances of each species in over 50 tropical countries. By this time there was growing evidence from the provenance tests that there were two taxa represented in the seed that had been distributed as *P. oocarpa* and some of the provenances of this species were re-identified as *P. patula* Schiede & Deppe ssp. *tecunumanii* (Eguiluz & Perry) Styles (Barnes & Styles, 1983; Styles, 1985; McCarter & Birks, 1985; Birks & Barnes, 1985).

Growth data from the provenance trials were sent to the OFI by some participating organizations on an informal basis and they were used to make an early assessment of performance (Greaves, 1980). Many early results have also been reported independently at successive meetings of the IUFRO Working Party on breeding tropical tree species (Nikles & Burley, 1972, 1973a, 1973b; Nikles *et al.*, 1978; Barnes & Gibson, 1984b; Gibson *et al.*, 1990). In 1977 it was recognized that the full value of the trials could only be realized if there was a coordinated approach to assessment in the trials to produce a comprehensive and comparable set of data from the whole range of environments over which they had been established. By then, the average age of the trials was seven years. In most tropical pine plantations severe competition has set in by the seventh or eighth year, maximum basal area carrying capacity of the site has been reached and provenances will have shown their capacity to exploit the site in this respect. Where a sawlog rotation is intended, thinning cannot be delayed beyond this stage if initial spacing has been at the standard 3m × 3m. In this case it would be the last stage at which the full tree complement of the crop could contribute to the analysis (Barnes & Gibson, 1984a). It was therefore a logical point at which to undertake a major evaluation programme.

Sixteen key *P. caribaea* and thirteen key *P. oocarpa/P. patula* ssp. *tecunumanii* trials were selected for an intensive assessment programme. Work was coordinated through genetics research schemes funded by the Overseas Development Administration of the United Kingdom (ODA) at the OFI, and completed between 1978 and 1981. The objectives were to determine differences in provenance performance across the complete range of climatic environments over which the species may be grown, to estimate the relative importance of genetic and environmental influences in the control of economically important traits, and to investigate the significance of provenance-environment interaction.

The intention was that the results of the analysis of the data for the individual trials would be published by scientists in the participating agencies (e.g. Liegel *et al.*, 1980; Brigdon *et al.*, 1980, Eisemann *et al.*, 1980), and that the results of the combined analysis would be published by the coordinators at the OFI (eg. Gibson, 1982; Barnes *et al.*, 1983, 1984; Birks & Barnes, 1985). Originally the plan was to publish the results in separate journal papers for groups of trials by species. However, there are many results that have not yet been published and may never be included in journal articles either because the data do not fit into a particular orthogonal set or because projects have ended and staff have moved. The existence of these analyses, however, is well known and there have been frequent requests for data from scientists in many countries both for their empirical informative value and for use in carrying out further statistical or genetic research.

In 1987, the ODA funded a Research Scheme at the OFI titled "Efficiency of experimental design in the genetic improvement of tropical tree species". One of the objectives of this project was to assemble essential statistics from data of all relevant tropical pine provenance and progeny tests held at the OFI; the data from the coordinated assessment of the international provenance trials of *P. caribaea*, *P. oocarpa* and *P. patula* ssp. *tecunumanii* are included. In the process of producing these statistics, all the data have been included and this has necessitated the use of more complex statistical procedures to deal with the non-

orthogonality so introduced. These summary statistics and analyses are presented in this *Tropical Forestry Paper* together with an explanation of the statistical approach and an interpretation of the results. Many aspects of the extensive results reported could bear more detailed discussion than is given here. However, the intention in this publication is to present the results in a form that makes it possible to highlight and interpret those findings that are most important from the perspectives of immediate operational application and future research and, at the same time, to make them available for detailed information and personal interpretation by the reader.

2. The provenances

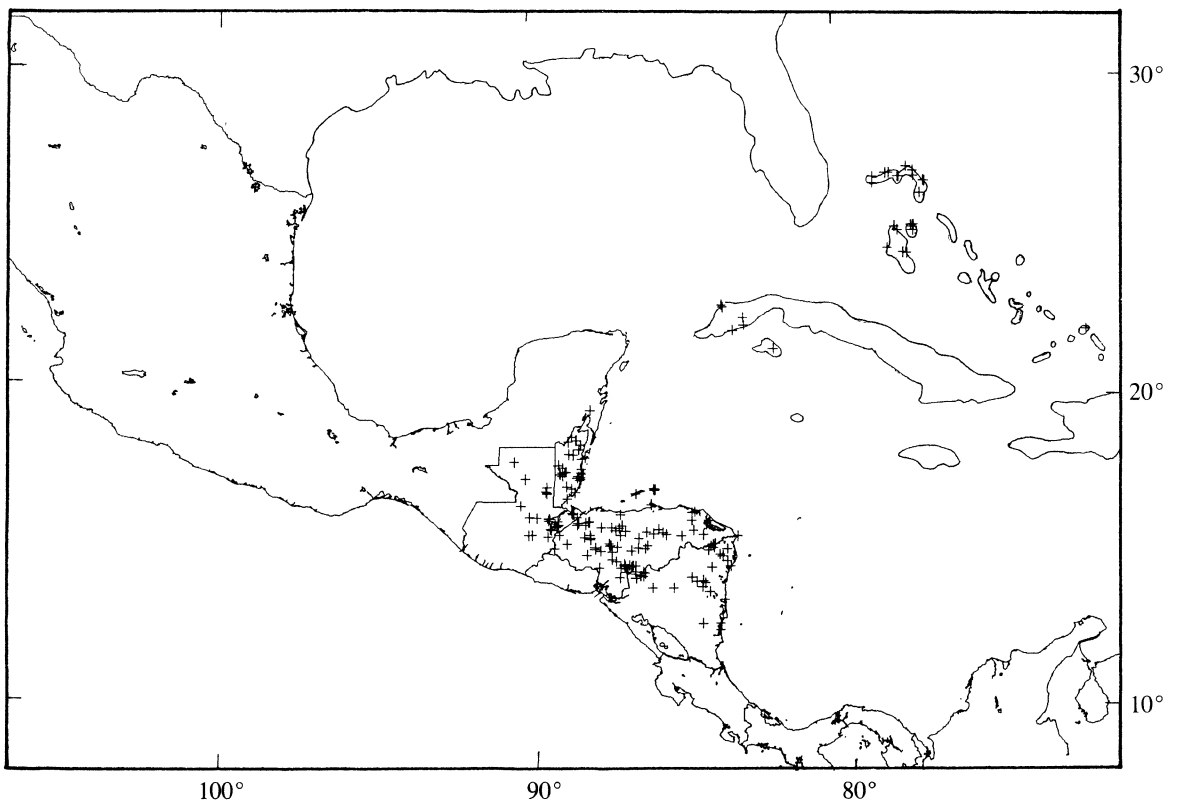
The natural distributions of the three varieties of *P. caribaea* are shown on Map 1 and those of *P. oocarpa* and *P. patula* ssp. *tecunumanii* on Maps 2 and 3 respectively (Styles, pers. comm.)¹

Seed collection details and full site descriptions for the provenances of *P. caribaea*, *P. oocarpa* and *P. patula* ssp. *tecunumanii* are given in previous publications (Greaves 1978, 1979). Locality and site details are summarized in Tables 1 and 2. In most instances, the rainfall and temperature figures are estimated by interpolation using the closest meteorological stations.

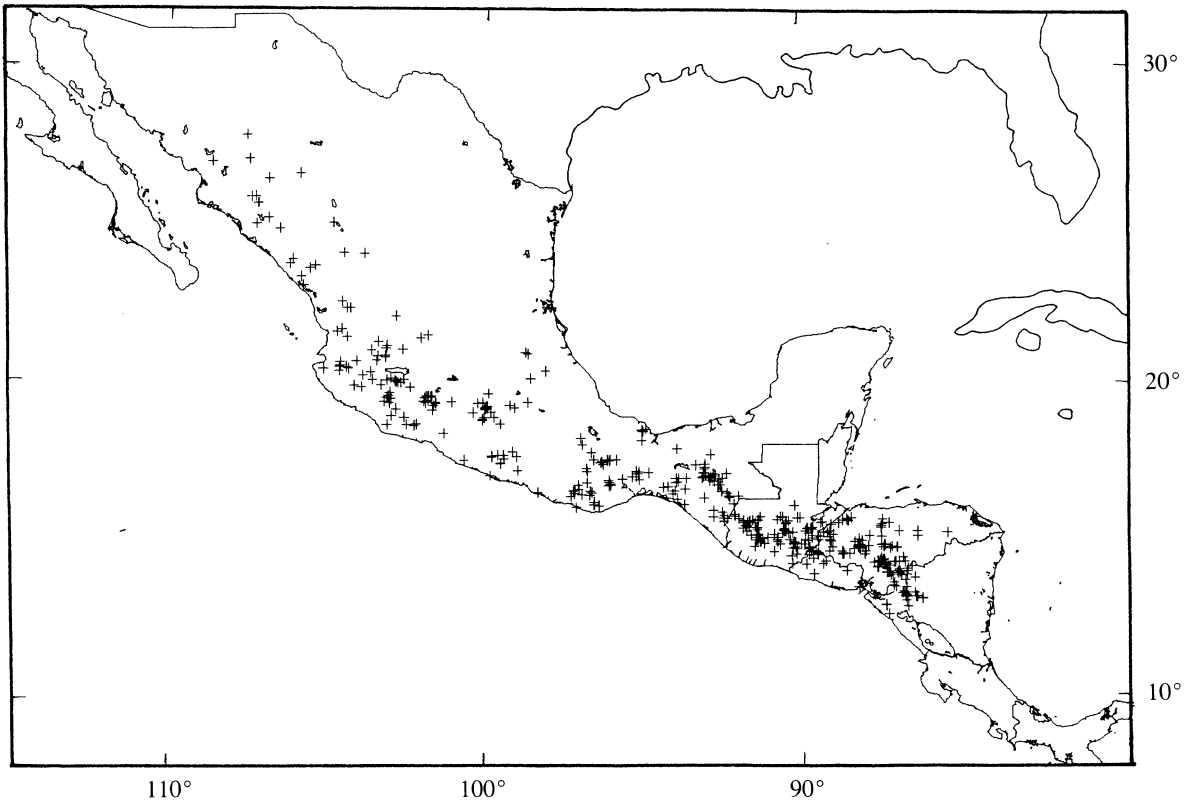
The locations of provenance seed collection sites are shown for *P. caribaea* var. *hondurensis* and *P. oocarpa*/*P. patula* ssp. *tecunumanii*, on Maps 4 and 5 respectively.

Equivalent maps for *P. caribaea* vars. *caribaea* and *bahamensis* are not given since the former were collected within only one degree of latitude and longitude on the west side of the main island of Cuba and there was only a single collection of the latter on Andros Island.

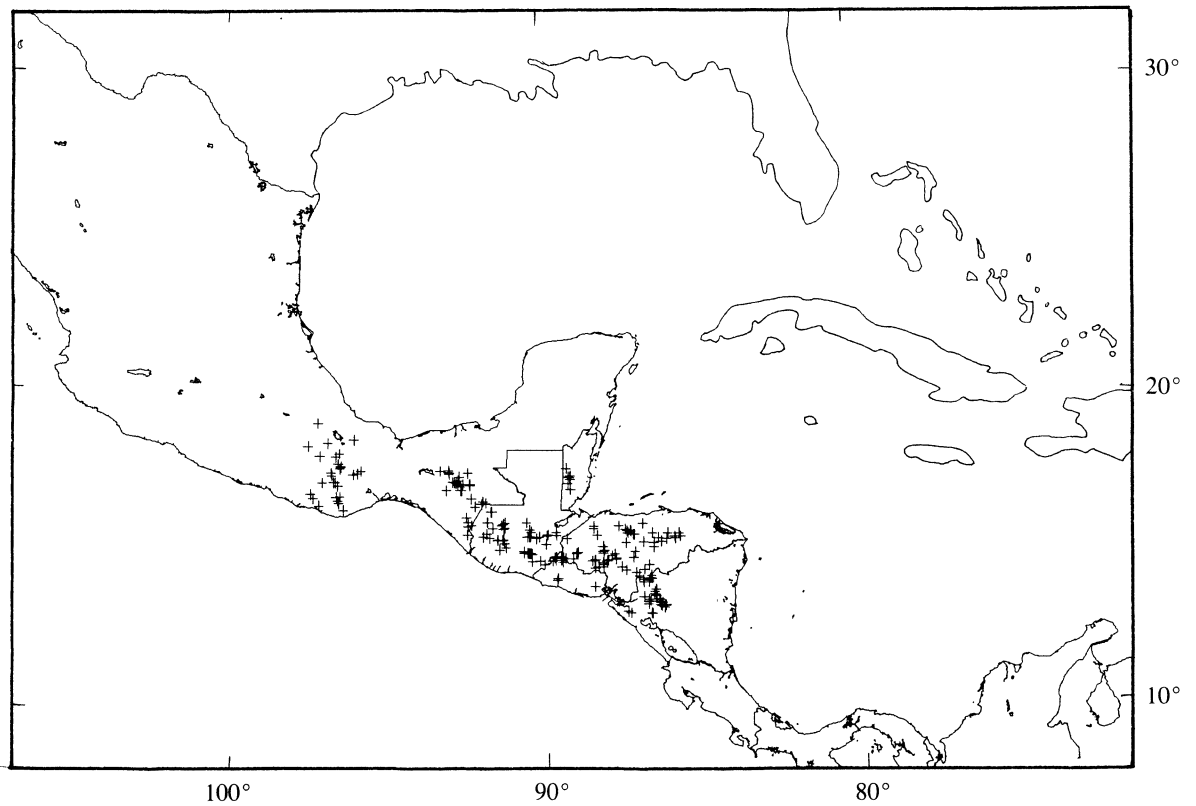
¹Dr. B.T. Styles, Oxford Forestry Institute, University of Oxford.



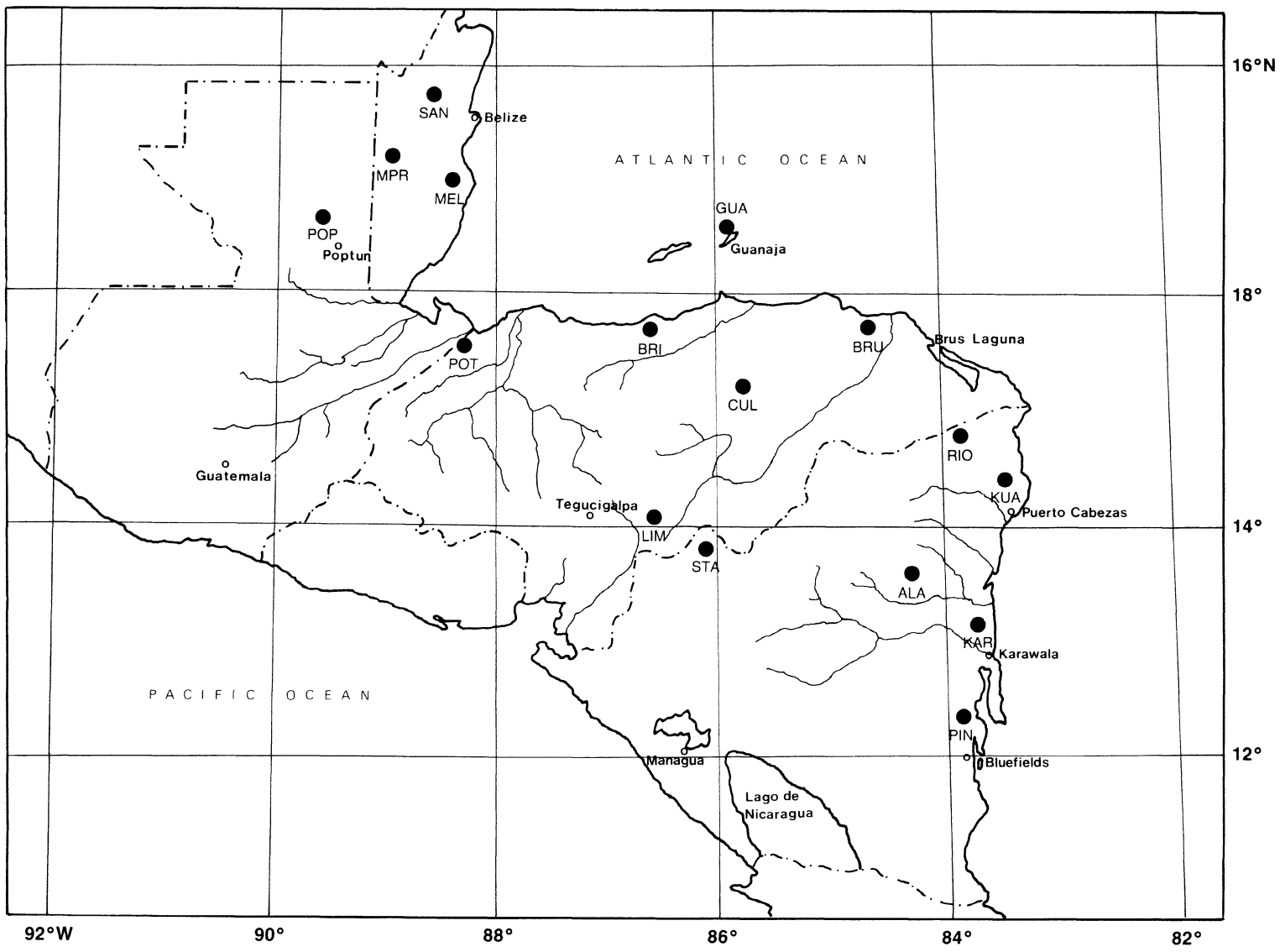
Map 1 Natural distribution of *Pinus caribaea*



Map 2 Natural distribution of *Pinus oocarpa*



Map 3 Natural distribution of *Pinus patula* ssp. *tecunumanii*

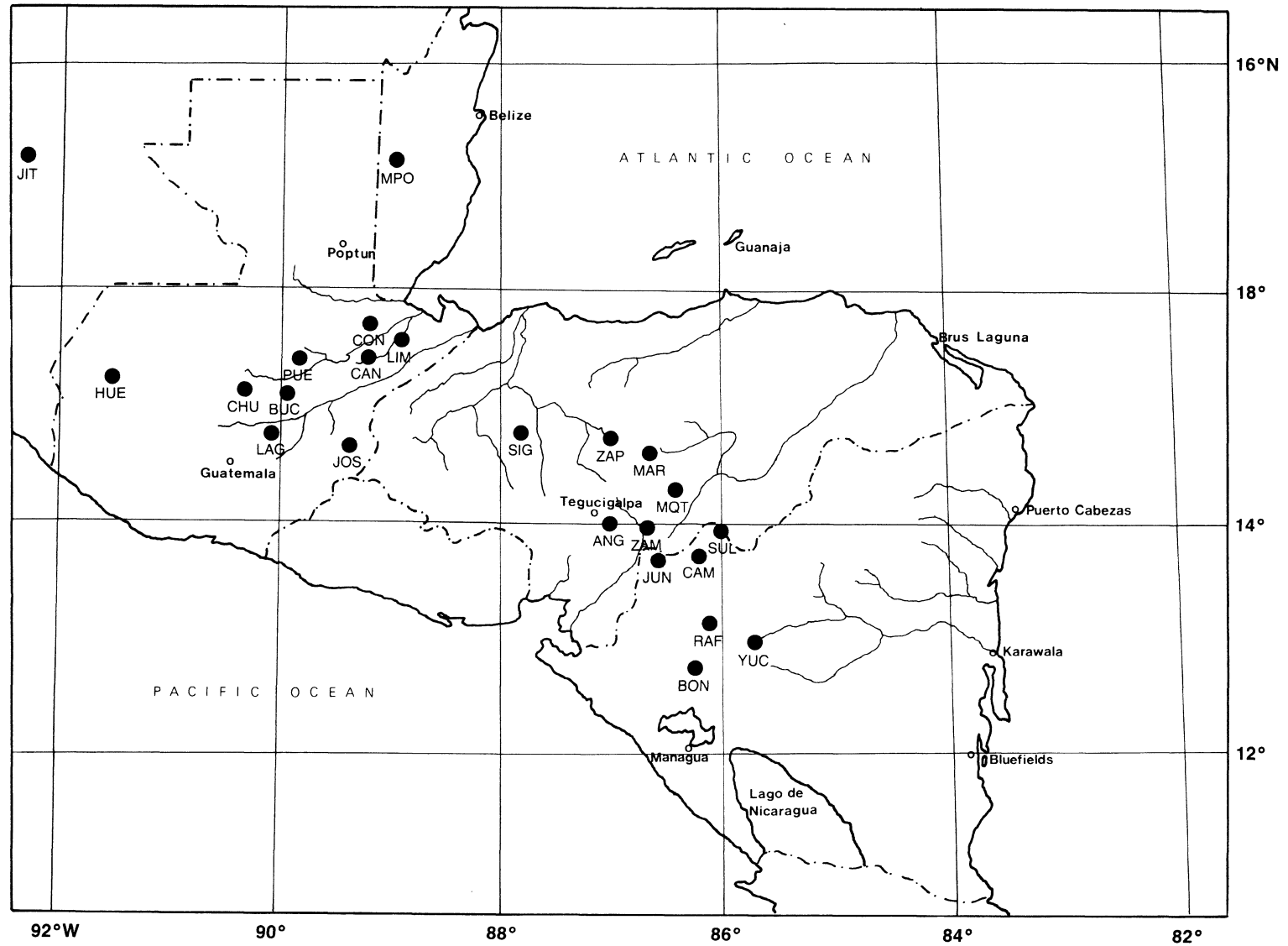


Map 4 Location of *Pinus caribaea* var. *hondurensis* provenance seed collections.

Table 1. Details of *Pinus caribaea* provenances used in the international trials (Greaves, 1978).

Provenance	Country	Code	Latitude	Longitude	Altitude (m)	Mean annual rainfall (mm)	Mean annual temperature (°C)
<i>var. hondurensis</i>							
Kuakil	Nicaragua	KUA	14°12'N	83°30'W	20	3208	26.5
Karawala	Nicaragua	KAR	12°58'N	83°34'W	10	3897	26.4
Alamicamba	Nicaragua	ALA	13°34'N	84°17'W	25	2610	27.3
Laguna el Pinar	Nicaragua	PIN	12°13'N	83°42'W	10	4180	26.4
Rio Coco	Nicaragua	RIO	14°45'N	83°55'W	75	2863	25.8
Poptun	Guatemala	POP	16°21'N	89°25'W	500	1688	24.2
Brus Laguna	Honduras	BRU	15°45'N	84°40'W	10	2840	26.5
Guanaja	Honduras	GUA	16°27'N	85°54'W	75	2308	27.1
Los Briones	Honduras	BRI	15°34'N	86°44'W	600	912	24.0
Los Limones	Honduras	LIM	14°03'N	86°42'W	700	663	22.2
Culmi	Honduras	CUL	15°06'N	85°37'W	550	1325	24.3
Potosi	Honduras	POT	15°20'N	88°25'W	650	1205	23.7
Santos	Honduras	SAN	17°34'N	88°33'W	30	1818	26.2
Mt. Pine Ridge	Belize	MPR	17°00'N	88°55'W	400	1558	23.9
Santa Clara	Nicaragua	STA	13°48'N	86°12'W	700	1818	23.4
Byfield*	Australia	BYF	22°50'S	150°39'E	10	1820	21.6
Melinda	Belize	MEL	17°01'N	88°20'W	12	2137	26.9
<i>var. caribaea</i>							
Marbajita	Cuba	MAR	22°48'N	83°29'W	80	1675	24.3
Los Palacios	Cuba	PAL	22°34'N	83°12'W	50	1477	24.4
Los Cabanos	Cuba	CAB	22°40'N	83°23'W	160	1675	24.3
Manuel	Cuba	MAN	22°37'N	83°40'W	150	1477	24.4
Caya la Mula	Cuba	CAL	22°33'N	83°48'W	110	1477	24.4
El Buren	Cuba	BUR	22°45'N	83°28'W	300	1675	24.3
Batey	Cuba	BAT	22°50'N	83°27'W	50	1553	24.3
<i>var. bahamensis</i>							
Andros Island	Bahama Islands	AND	24°53'N	78°07'W	3	1055	25.4

*Bred exotic source



Map 5 Location of *Pinus oocarpa* and *P. patula* ssp. *tecunumanii* provenance seed collections.

Table 2. Details of *Pinus occarpa* and *P. patula* ssp. *tecunumanii* provenances used in the international trials (Greaves, 1979).

Provenance	Country	Code	Latitude	Longitude	Altitude (m)	Mean annual rainfall (mm)	Mean annual temperature (°C)
<i>P. occarpa</i>							
Sullates	Nicaragua	SUL	13°51'N	86°16'W	1050	1845	21.6
Zapotillo	Honduras	ZAP	14°37'N	87°02'W	1000	1272	21.8
San Marcos	Honduras	MAR	14°36'N	87°00'W	1100	1272	21.3
Canas	Guatemala	CAN	15°10'N	89°23'W	1200	1900	21.3
Lima	Guatemala	LIM	15°11'N	89°21'W	1000	1800	22.4
Conacaste	Guatemala	CON	15°10'N	89°21'W	600	1900	24.6
Maraquito	Honduras	MQT	14°13'N	86°50'W	1000	1272	21.8
Agua Fria	Honduras	AGF	15°16'N	87°06'W	1100	1069	21.6
Pueblo Caido	Guatemala	PUE	15°12'N	89°18'W	800	1900	23.5
Junquillo	Nicaragua	JUN	13°42'N	86°35'W	1000	904	21.8
Bonete	Nicaragua	BON	12°50'N	86°18'W	950	922	21.4
Bucaral	Guatemala	BUC	15°01'N	90°09'W	1150	900	21.6
Angeles	Honduras	ANG	14°07'N	87°04'W	1300	920	20.2
Zamorano	Honduras	ZAM	14°02'N	87°03'W	1100	1117	20.4
Lagunilla	Guatemala	LAG	14°42'N	89°57'W	1600	936	19.5
Siguatpeque	Honduras	SIG	14°32'N	87°50'W	1100	1247	19.9
Chuacus	Guatemala	CHU	15°02'N	90°16'W	1300	890	22.5
San Jose	Guatemala	JOS	14°28'N	89°28'W	1000	956	22.4
Huehuetenango	Guatemala	HUE	15°13'N	91°32'W	1700	1037	16.9
Jitotol	Mexico	JIT	17°05'N	92°30'W	1650	1200	16.5
<i>P. patula</i> ssp. <i>tecunumanii</i>							
Mt. Pine Ridge	Belize	MPO	17°00'N	88°55'W	700	2064	21.2
Camelias	Nicaragua	CAM	13°46'N	86°18'W	900	1500	22.4
Yucul	Nicaragua	YUC	12°55'N	85°47'W	900	1394	22.4
Rafael	Nicaragua	RAF	13°14'N	86°08'W	1200	1366	20.8

3. The trials

The *P. caribaea* and *P. oocarpa/P. patula* ssp. *tecunumanii* trials selected for assessment are listed in Tables 3 and 4 with relevant locality and design details. The trial localities are shown on Map 6.

4. Traits assessed

The principles of trial design and management and the traits selected for assessment are described by Barnes & Gibson (1984). A full list of traits measured in the international provenance trials is given by Gibson (1982). Those primary and derived traits that have been included in this *Tropical Forestry Paper* are listed below.

1. Survival (%)
2. Total height (m)
3. Diameter at breast height over bark (cm)
4. Bark thickness (mm) – mean of two measurements taken at right angles to each other at breast height (1.3 m).
5. Stem volume under bark (dm³) – estimated from underbark diameter at breast height, total height and a form quotient based on under bark circular areas at breast height and at 6 m (measured over bark and estimated under bark).
6. Bark percent (%) – bark volume based on breast height measurement of bark thickness expressed as a percentage of total overbark volume.
7. Stem straightness (index) – based on an assessment of straightness in 1-m sections of the first 6 m of stem (see Barnes & Gibson, (1986) for method and index construction).
8. Stem lean (%) – percentage of trees in plot with stem lean greater than 2.5°.
9. Multiple stems (%) – percentage of trees in the plot with forks or multiple stems.
10. Branches per whorl (number) – estimated mean value for the whole tree.
11. Whorls per unit length of stem (number) – count of number of whorls between 1 and 6 m from the ground.
12. Longest internode (m) – measured length of longest internode.
13. Fineness of branches (%) – the percentage of trees in the plot with fine or fine/medium branch thickness being trees in the first two categories in a scale of five classes.
14. Coning percent (%) – the percentage of trees in the plot bearing cones.
15. Pilodyn penetration (mm).
16. Wood basic density (g cm⁻³) – determined from a increment borer core of 8 mm diameter taken through the tree at breast height and then calculated as oven-dried weight over volume calculated from nominal diameter and fresh length of core.
17. Pinene (%) – the percentage of trees in the plot with α -pinene + β -pinene > 80% of terpene composition (by weight) determined by gas liquid chromatography (GLC) on a sample taken from the stem between 30 and 50 cm from ground level.
18. Δ -3-carene (ratio) – α -pinene, β -pinene and β -phellandrene are valuable components of the oleoresin, Δ -3-carene is an undesirable component. The ratio of (α -pinene + β -pinene + β -phellandrene) percentage of total oleoresin to Δ -3-carene percentage of total oleoresin (by weight) is a measure of the value of the oleoresin that does not depend on the percentage of other terpenes present.

Every tree in the plot was assessed for all traits except wood density and resin content. Wood density was assessed in the three largest trees in each plot. Oleoresin samples were taken from the three largest trees per plot plus two more taken at random. Resin samples were not produced from every tree tapped.

5. Statistical analysis

5.1 Form of the data

The measured traits that were continuous variables were straightforward to analyse, as were those that were counts where the range of numbers was large enough to approximate to a continuous distribution.

Where the trait was assessed categorically in more than two classes or assessed as a count of small numbers, the data were changed to be binary before analysis. For example, cone production, which consisted of estimates of the number of cones on a tree in five categories, was compressed to two classes, zero and with cones.

The data from the GLC analysis of terpenes in the oleoresin samples were compositional in that the proportions of all constituents were constrained to sum to 100. The statistical objections to analysing proportional data by inappropriate methods have been discussed elsewhere (Birks & Kanowski, 1988). The objections were overcome here by converting the data to two categories and analysing it in the binary form as described above, or by converting it to ratios of constituents and using a log transformation before analysis as a continuous trait.

5.2 Experimental design and analysis

Experimental design in all the trials was randomized complete block except for two of the *P. oocarpa* trials, Loudima (Congo) and San Pedro (Ivory Coast), which were incomplete block. The plots were of uniform size. The number of replications varied between trials from two to ten, and plot size from five trees in a line to a 10 × 10-tree plot. Spacing varied from square to rectangular, and initial stocking from 833 to 1600 stems per hectare. Details are given in Tables 3 and 4.

The analysis of the binary data was carried out by fitting a generalized linear model, the details of which follow.

The N plots of a randomized complete block design are of a uniform size initially containing n_p trees. At the time of assessment a number of trees could have been lost and the number of trees remaining n_i , varies between 0 and n_p , where $i = 1, \dots, N$. The number of positive responses (i.e. that is the number of trees possessing the characteristic) is y_i out of n_i trees. The measured fraction with the positive response is y_i/n_i .

If the observations on all individual trees are independent and the probability of a positive response is constant for all trees in a plot, then the distribution of y_i , given n_i is binomial with parameter π_i , such that

$$\begin{aligned} \text{prob}(y_i=0) &= 1 - \pi_i & \text{prob}(y_i=1) &= \pi_i \\ \text{var}(y_i) &= n_i \pi_i (1 - \pi_i) & E(y_i) &= n_i \pi_i \\ \pi_i &\text{ is estimated by } y_i/n_i \end{aligned}$$

For an individual experiment, π_i depends on the block and the provenance. It is not possible to express π_i as a linear combination of provenance and block effects because of the constraint on the range of values that π_i can take

$$0 \leq \pi_i \leq 1$$

π_i must instead be transformed to a function $f(\pi_i)$ that is not constrained.

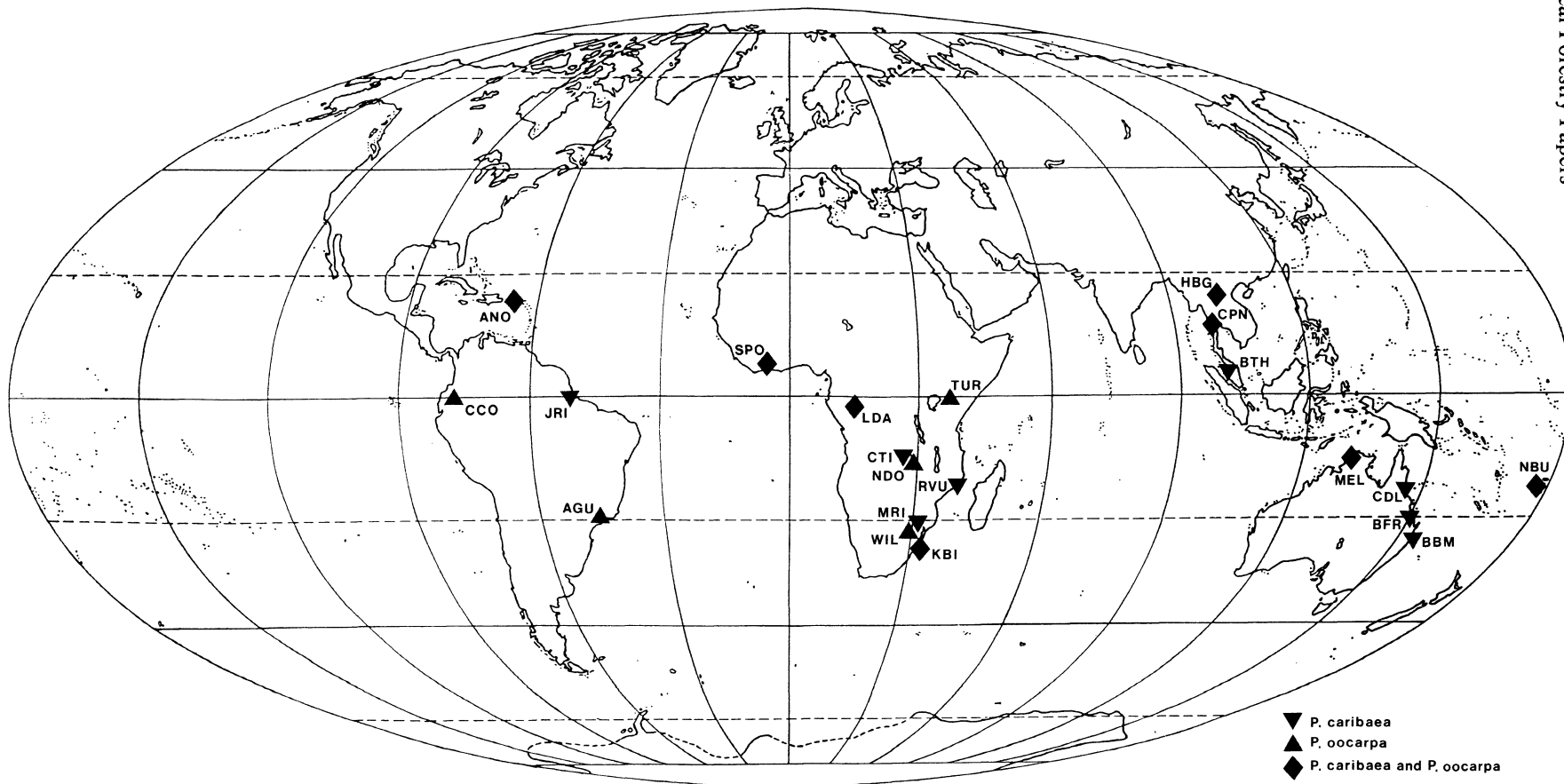
The usual function chosen is the logit

$$f(\pi) = \ln \left[\frac{\pi}{1 - \pi} \right]$$

The analysis was carried out using the generalized linear model program of GENSTAT.

The provenance-locality tables used in the combined locality analyses were constructed from the results of the individual trial analyses.

Provenance representation varied from trial to trial. On average, about one third of all possible entries in the provenance-locality tables were missing (See Tables 5 to 40). This non-orthogonality in the combined trial data created a problem in the prediction of provenance performance over sites; comparisons between provenances would be biased unless provenance means are corrected to take into account the different sub-set of localities in which each provenance was grown.



Map 6 Provenance trial locations.

Table 3. Details of *Pinus caribaea* international provenance trial locations.

Location	Country	Code	Latitude	Longitude	Altitude (m)	Mean annual rainfall (mm)	Mean annual temperature (°C)	Trees per plot	Number of replications	Spacing (m)	Age at assessment (yr)
Byfield Ridge	Australia	BFR	22°50'S	150°39'E	30	1745	21.8	7 × 7	5	2.7 × 2.5	6.1
San Pedro	Ivory Coast	SPO	4°45'N	6°43'W	20	1900	26.0	10 × 6	5	4.0 × 2.0	9.8
Huey Bong	Thailand	HBG	18°12'N	98°35'E	790	1191	22.1	6 × 6	5	3.0 × 3.0	6.5
Chumporn	Thailand	CPN	10°52'N	99°15'E	70	2071	26.8	6 × 6	5	3.0 × 3.0	6.5
Jari	Brazil	JRI	0°52'S	52°33'W	80	2500	26.5	7 × 7	5	3.0 × 3.0	6.3
Loudima	Congo	LDA	4°13'S	13°05'E	150	882	24.6	6 × 6	5	2.5 × 2.5	8.3
Nabou	Fiji	NBU	17°59'S	177°15'E	30	2314	25.5	6 × 6	5	3.0 × 3.0	6.9
Bukit Tapah	Malaysia	BTH	4°20'N	101°18'E	549	3334	24.3	6 × 6	3	2.5 × 2.5	5.5
Anasco	Puerto Rico	ANO	18°20'N	17°07'W	175	5220	25.3	7 × 1	10	2.7 × 2.7	5.8
KwaMbonambi	RSA	KBI	28°45'S	32°00'E	65	1338	22.0	6 × 6	5	2.7 × 2.7	7.2
Mariti	RSA	MRI	24°54'S	30°56'E	1000	1556	17.3	6 × 6	5	2.7 × 2.7	6.3
Ruvu	Tanzania	RVU	6°53'S	38°55'E	70	1125	25.7	4 × 4	4	2.5 × 2.5	4.8
Chati	Zambia	CTI	13°00'S	29°00'E	1300	1273	20.5	10 × 10	4	3.0 × 3.0	7.2
Melville Is.	Australia	MEL	11°25'S	131°00'E	49	1968	27.2	7 × 7	4	3.0 × 4.0	5.9
Beerburrum	Australia	BBM	27°00'S	153°00'E	12	1546	20.8	10 × 1	5	3.0 × 3.0	6.0
Cardwell	Australia	CDL	18°16'S	146°03'E	20	2127	24.1	7 × 7	5	2.7 × 2.5	6.0

Table 4. Details of *Pinus occarpa/P. patula* ssp. *tecunumanii* international provenance trial locations.

Location	Country	Code	Latitude	Longitude	Altitude (m)	Mean annual rainfall (mm)	Mean annual temperature (°C)	Trees per plot	Number of replications	Spacing (m)	Age at assessment (yr)
Melville Is.	Australia	MEL	11°25'S	131°00'E	49	1968	27.2	10	3	3.0 × 4.0	5.9
Agudos	Brazil	AGU	22°22'S	48°32'W	550	1300	20.5	16	4	3.0 × 3.0	6.3
Loudima	Congo	LDA	4°13'S	13°05'E	150	882	24.6	16	5	2.5 × 2.5	9.3
San Pedro	Ivory Coast	SPO	4°45'N	6°43'W	20	1900	26.0	16	1-3	2.5 × 2.5	9.0
Conocoto	Ecuador	CCO	0°16'S	78°25'W	2500	1386	15.2	6	5	2.0 × 2.0	6.2
Nabou	Fiji	NBU	17°59'S	177°25'E	30	2314	25.5	5	10	3.0 × 3.0	6.9
Turbo	Kenya	TUR	0°38'N	35°04'E	1700	1300	18.0	16	4	3.0 × 3.0	7.6
Anasco	Puerto Rico	ANO	18°20'N	67°07'W	175	882	24.6	7	5	2.7 × 2.7	5.7
Wilgeboom	RSA	WIL	24°58'S	30°58'E	945	1000	17.5	16	5	2.7 × 2.7	7.5
KwaMbonambi	RSA	KBI	28°45'S	32°00'E	65	1338	22.0	16	5	2.7 × 2.7	7.2
Huey Bong	Thailand	HBG	18°12'S	98°25'E	790	1191	22.1	16	3	3.0 × 3.0	6.5
Chumporn	Thailand	CPN	10°52'N	99°15'E	70	2071	26.8	16	2	3.0 × 3.0	6.5
Ndola	Zambia	NDO	13°00'S	29°00'E	1300	1212	20.5	16	2	3.0 × 3.0	6.1

The method of least squares was used to predict adjusted provenance values over all localities. If y_{ij} is the mean of the i th provenance at the j th locality, the model is

$$y_{ij} = \mu + p_i + l_j + e_{ij}$$

where μ is the overall mean

p_i is the effect of the i th provenance

l_j is the effect of the j th locality

and e_{ij} is the error associated with the i th provenance at the j th locality.

The p_i and the l_j are estimated by minimizing

$$\sum_{i=1}^p \sum_{j=1}^l e_{ij}^2$$

with respect to the unknown parameters.

The y_{ij} are also measured with varying accuracies due to differences between experiments (eg. plot size, replication number, climatic factors etc.). The least squares estimation of effects would have taken these different precisions into account by weighting each value of y_{ij} by the inverse of its variance. When this procedure was used, however, the predicted provenance means over all sites differed only slightly from the unweighted means and the ranking of provenances did not change. An unweighted analysis was therefore accepted. The predicted provenance mean at each locality was calculated using the estimated effects and provenance mean over localities was derived from these for all the continuous variables. This follows the method of Yates (1933), usually called the "fitting constants" method.

A procedure similar to the above fitting constants method was used for the combined trials analyses of the binary traits. Provenance-locality tables were constructed. Each cell of the table contained two values, n_{ij} , the number of trees assessed and y_{ij} , the number of positive responses. y_{ij}/n_{ij} is the estimate of π_{ij} , the probability of a positive response in the i th cell. The logit of the binomial parameter was modelled by a linear equation of provenance and locality effects.

5.3 Genotype-environment interaction

The formal statistical estimates of genotype-environment (gei) interaction have been made elsewhere. These were extensively studied for 10 traits of an orthogonal subset of the *P. caribaea* data by Gibson (1982). Extensive analysis for gei in *P. oocarpa* has not been undertaken. The size of the equivalent orthogonal subset that can be extracted from the provenance-locality table for *P. oocarpa* is much smaller than that used for *P. caribaea*. Consequently, an analysis of this small data set would be of limited interest as most of the available information would not be used.

6. Results

The results of the analyses are given in Tables 5 to 40 for each trait separately for each species. The order of provenances is the same in each table and has no significance other than that it is in accordance with the site numbers allocated by Greaves (1978 and 1979). The body of each table consists of the provenance means in localities. Overall provenance and site corrected means are given together with their standard errors. The standard error of a provenance mean in each locality is shown, followed by the significance level of the variance ratio which tests for differences between provenances in the analysis of variance. Within plot variances are not given although there was evidence of significant variation in this feature for the productivity traits of *P. caribaea* (Gibson *et al.*, 1983a). This could have been due to differences in allelic frequencies, to different numbers of allelic polymorphisms, to hybridization with *P. oocarpa* (Styles *et al.*, 1982), or to different levels of inbreeding. As the trial design here does not permit an apportionment of the variation to these sources and as each demands a different approach in breeding strategy, a study of between tree variation is left to the second stage trials (Crockford *et al.*, 1990) in which there is a family structure.

Table 7. Provenance-locality mean tree values of breast height diameter over bark (cm) for 25 provenances of *Pinus caribaea* at 16 localities.

Prov	BFR	SPO	HBG	CPN	JRI	LDA	NBU	BTH	ANO	KBI	MRI	RVU	CTI	MEL	BBM	CDL	Corr. mean	s.e.
KUA	13.0	17.6	7.8	-	-	-	17.0	-	-	16.2	13.6	-	19.8	-	15.4	13.6	14.3	.22
KAR	14.2	17.9	8.3	13.7	15.7	-	18.3	-	13.7	-	-	-	-	-	16.1	13.9	14.7	.22
ALA	13.7	18.2	8.8	14.5	16.6	15.8	18.5	14.2	13.9	16.2	13.9	8.5	18.8	13.5	15.8	14.5	14.9	.16
PIN	14.1	-	-	-	-	-	18.9	-	-	-	-	-	-	-	-	14.0	15.1	.38
RIO	13.9	16.7	8.7	15.0	16.4	15.8	18.8	13.4	13.1	-	-	9.1	-	13.6	15.6	13.2	14.8	.18
POP	14.5	16.9	8.6	15.5	15.8	-	17.8	13.8	13.9	16.8	14.2	8.8	20.4	12.8	17.2	14.1	15.0	.16
BRU	13.8	17.3	8.9	13.3	15.4	15.2	17.2	13.2	12.8	16.2	13.9	6.2	17.7	13.2	16.3	13.6	14.2	.16
GUA	15.2	18.2	8.2	15.5	17.2	15.8	20.3	15.0	13.3	17.3	14.8	-	19.6	13.4	17.1	14.8	15.5	.16
BRI	14.2	17.7	-	-	-	-	-	-	13.2	-	-	-	-	-	-	-	14.9	.32
LIM	13.2	17.8	9.2	-	16.6	-	17.2	-	-	-	-	9.3	-	-	-	13.4	14.8	.25
CUL	14.8	17.2	9.0	15.0	16.8	15.5	17.7	-	13.5	-	14.0	9.0	-	-	-	13.6	15.0	.20
POT	14.0	17.6	9.5	16.0	15.3	15.8	19.5	14.0	14.5	-	14.4	7.8	20.0	-	17.0	14.4	14.5	.17
SAN	13.0	17.3	-	15.5	16.3	-	17.4	-	-	-	-	-	-	12.6	15.4	13.5	14.5	.23
MPR	14.3	16.7	-	-	16.2	15.6	17.7	15.0	13.9	16.9	14.8	9.2	-	13.4	-	14.4	15.1	.19
STA	13.7	17.5	7.8	14.6	16.2	15.3	18.1	14.6	13.5	-	15.1	8.9	19.7	-	17.6	13.8	15.0	.17
BYF	14.9	17.4	8.8	-	-	15.8	18.8	-	14.8	-	14.6	8.5	-	13.4	17.4	14.8	15.4	.19
MEL	13.4	-	-	-	16.3	-	18.2	14.8	12.6	15.3	-	-	-	13.0	15.3	14.3	14.6	.22
MAR	-	13.5	-	12.4	-	-	-	-	-	14.9	13.3	-	-	-	-	-	12.6	.33
PAL	-	-	-	-	14.5	13.5	-	-	10.3	14.0	12.9	6.6	-	10.6	-	-	12.7	.25
CAB	-	-	-	-	-	-	-	-	-	14.2	-	-	-	-	-	-	12.5	.66
MAN	-	-	-	-	13.1	-	-	-	-	14.4	-	-	-	-	-	-	12.2	.46
CAY	-	-	-	-	-	-	-	12.0	-	14.4	12.9	-	-	-	-	-	12.9	.38
BUR	-	14.2	-	12.9	-	-	-	-	11.4	14.7	12.8	-	17.3	-	-	-	12.8	.27
BAT	-	-	-	-	-	-	-	-	-	14.5	-	-	-	-	-	-	12.8	.66
AND	-	-	7.9	11.0	13.1	11.7	-	12.6	9.5	-	-	7.3	16.7	9.5	-	-	12.1	.22
Corr. mean	13.2	16.6	8.0	14.0	15.5	14.7	17.5	13.6	12.6	15.9	13.8	7.9	18.7	12.4	15.7	13.3		
s.e.	.16	.16	.19	.19	.17	.20	.17	.20	.17	.18	.18	.19	.22	.20	.19	.16		
s.d.	.36	.40	.46	.66	.53	.30	.52	.45	.53	.38	.46	.44	.32	.34	.30	.32		
F.pr.	***	***	NS	***	***	***	**	***	***	***	**	***	***	***	***	**		

Table 8. Provenance-locality mean tree value of bark thickness (mm) for 25 provenances of *Pinus caribaea* at 16 localities.

Prov	BFR	SPO	HBG	CPN	JRI	LDA	NBU	BTH	ANO	KBI	MRI	RVU	CTI	MEL	BBM	CDL	Corr. mean	s.e.
KUA	12.4	14.5	11.7	-	-	-	15.0	-	-	18.4	17.0	-	20.2	-	15.6	13.6	14.3	.26
KAR	14.1	15.3	12.1	12.0	13.4	-	16.6	-	15.1	-	-	-	-	-	17.0	13.1	14.9	.25
ALA	13.2	14.6	12.4	12.4	14.0	12.2	16.0	16.0	14.0	17.6	17.5	9.8	20.3	17.9	15.6	13.7	14.6	.19
PIN	13.9	-	-	-	-	-	16.3	-	-	-	-	-	-	-	-	12.4	14.6	.45
RIO	14.5	15.3	12.4	13.5	14.2	13.1	16.5	17.6	13.8	-	-	10.1	-	18.2	15.8	12.9	15.1	.21
POP	13.8	13.2	12.3	13.2	14.2	-	14.3	15.6	14.1	19.3	17.6	9.4	21.1	17.3	18.0	13.5	14.8	.20
BRU	13.5	14.4	12.3	12.1	13.1	13.2	15.4	16.0	13.7	18.4	17.2	7.0	18.6	16.7	15.8	13.3	14.2	.19
GUA	16.4	16.3	12.9	15.5	16.2	14.7	20.7	20.4	15.5	21.3	19.4	-	21.8	20.0	18.4	15.2	17.0	.20
BRI	15.1	15.0	-	-	-	-	-	-	14.0	-	-	-	-	-	-	-	14.1	.38
LIM	14.3	17.4	13.2	-	15.7	-	17.7	-	-	-	-	11.0	-	-	-	14.4	16.3	.29
CUL	14.1	15.2	12.2	12.9	14.3	13.3	15.1	-	13.7	-	18.4	9.1	-	-	-	13.5	14.8	.23
POT	15.3	17.0	13.3	15.3	14.0	14.6	18.6	18.5	16.1	-	18.9	9.8	22.1	-	19.1	14.6	16.4	.20
SAN	14.6	15.4	-	15.4	16.2	-	17.0	-	-	-	-	-	-	18.7	17.2	15.0	16.1	.27
MPR	13.6	13.8	-	-	14.6	14.7	16.2	17.8	14.9	19.2	18.8	10.2	-	18.2	-	13.9	15.4	.22
STA	13.8	15.6	11.8	13.6	14.6	13.7	17.6	18.1	13.9	-	20.0	9.7	20.9	-	17.8	14.2	15.6	.20
BYF	13.9	14.0	12.6	-	-	13.8	15.6	-	15.3	-	18.1	9.6	-	17.8	16.8	14.9	15.2	.23
MEL	13.8	-	-	-	15.7	-	17.6	17.4	14.0	18.4	-	-	-	19.1	16.9	14.6	15.6	.26
MAR	-	10.8	-	11.6	-	-	-	-	-	16.1	15.4	-	-	-	-	-	12.3	.39
PAL	-	-	-	-	14.2	12.2	-	-	11.6	15.8	15.7	7.4	-	15.3	-	-	13.1	.29
CAB	-	-	-	-	-	-	-	-	-	15.6	-	-	-	-	-	-	12.0	.78
MAN	-	-	-	-	11.8	-	-	-	-	15.9	-	-	-	-	-	-	12.4	.55
CAY	-	-	-	-	-	-	-	14.1	-	16.4	16.1	-	-	-	-	-	12.6	.45
BUR	-	11.3	-	10.6	-	-	-	-	12.4	15.3	15.3	-	17.3	-	-	-	12.2	.32
BAT	-	-	-	-	-	-	-	-	-	15.5	-	-	-	-	-	-	11.9	.78
AND	-	-	11.3	10.3	11.0	11.0	-	12.7	10.3	-	-	6.9	15.4	13.6	-	-	11.7	.26
Corr. mean	13.2	14.0	11.7	12.7	13.7	12.8	15.7	16.3	13.5	18.0	17.4	8.8	19.6	17.1	16.0	13.0		
s.e.	.20	.19	.22	.22	.20	.24	.20	.24	.20	.21	.21	.23	.26	.24	.23	.20		
s.d.	.42	.48	.37	.50	.62	.47	.56	.66	.43	.49	.48	.57	.72	.49	.43	.57		
F.pr.	***	***	*	***	***	***	***	***	***	***	***	***	***	***	***	*		

Table 9. Provenance–locality mean tree volume under bark (dm³) for 25 provenances of *Pinus caribaea* at 14 localities.

Prov	BFR	SPO	HBG	CPN	JRI	LDA	NBU	BTH	ANO	KBI	MRI	RVU	CTI	MEL	BBM	CDL	Corr. mean	s.e.
KUA	59	209	–	–	–	–	178	–	–	98	60	–	206	–	87	68	107.9	5.6
KAR	69	233	–	92	137	–	200	–	65	–	–	–	–	–	98	80	117.6	5.6
ALA	67	250	–	107	154	166	215	83	76	109	63	–	174	57	96	87	121.7	4.1
PIN	81	–	–	–	–	–	230	–	–	–	–	–	–	–	–	83	132.3	9.2
RIO	64	164	–	102	140	153	215	62	59	–	–	–	–	55	89	59	108.5	4.7
POP	74	194	–	111	128	–	185	78	69	109	65	–	226	42	110	78	115.1	4.3
BRU	62	208	–	68	136	144	180	69	54	100	60	–	162	52	109	74	105.6	4.1
GUA	75	235	–	100	172	159	250	79	54	117	66	–	198	51	114	86	125.0	4.1
BRI	64	206	–	–	–	–	–	–	58	–	–	–	–	–	–	86	116.2	8.0
LIM	53	206	–	–	154	–	160	–	–	–	–	–	–	–	–	67	105.9	7.1
CUL	80	194	–	107	159	141	183	–	66	–	57	–	–	–	–	68	113.9	5.3
POT	61	192	–	118	126	143	228	78	77	–	62	–	217	–	106	78	118.3	4.5
SAN	57	183	–	92	122	–	161	–	–	–	–	–	–	34	73	54	94.3	5.6
MPR	76	185	–	–	140	140	181	86	66	119	73	–	–	53	–	81	113.9	4.7
STA	62	217	–	90	158	150	192	89	69	–	76	–	226	–	125	74	121.8	4.5
BYF	78	224	–	–	–	151	228	–	81	–	74	–	–	54	120	88	128.4	5.3
MEL	60	–	–	–	141	–	202	91	53	81	–	–	–	45	90	75	108.1	5.3
MAR	–	90	–	55	–	–	–	–	–	80	52	–	–	–	–	–	63.8	8.0
PAL	–	–	–	–	96	89	–	–	26	66	46	–	–	21	–	–	74.7	6.5
CAB	–	–	–	–	–	–	–	–	–	69	–	–	–	–	–	–	73.6	16.2
MAN	–	–	–	–	75	–	–	–	–	71	–	–	–	–	–	–	61.4	11.3
CAY	–	–	–	–	–	–	–	52	–	66	41	–	–	–	–	–	79.9	9.3
BUR	–	114	–	68	–	–	–	–	41	79	45	–	141	–	–	–	72.4	6.5
BAT	–	–	–	–	–	–	–	–	–	75	–	–	–	–	–	–	79.6	16.2
AND	–	–	–	36	71	57	–	62	20	–	–	–	126	15	–	–	58.2	6.0
Corr. mean	52.9	186.2	–	86.1	128.5	128.2	185.1	69.2	51.6	96.2	56.2	–	181.8	39.4	87.8	61.4		
s.e.	4.0	4.0	–	4.6	4.1	5.0	4.2	5.0	4.2	4.4	4.4	–	5.5	5.0	4.8	4.0		
s.d.	5.6	15.2	–	13.0	15.1	7.3	16.6	8.9	8.5	7.1	7.3	–	10.8	3.3	5.7	4.8		
F.pr.	*	***	–	NS	***	***	*	*	***	***	**	–	***	***	***	***		

Table 10. Provenance–locality mean tree values of bark percentage of total tree volume (over bark) for 25 provenances of *Pinus caribaea* at 14 localities.

Prov	BFR	SPO	HBG	CPN	JRI	LDA	NBU	BTH	ANO	KBI	MRI	RVU	CTI	MEL	BBM	CDL	Corr. mean	s.e.	
KUA	32.4	26.0	–	–	–	–	27.6	–	–	36.7	40.6	–	31.9	–	33.3	33.5	33.4	0.5	
KAR	34.1	26.9	–	29.5	28.6	–	28.2	–	37.0	–	–	–	–	–	34.7	31.4	33.7	0.5	
ALA	32.6	25.0	–	27.8	28.0	24.4	26.7	36.5	33.9	34.9	40.8	–	33.5	42.3	32.6	31.4	32.2	0.4	
PIN	32.4	–	–	–	–	–	26.1	–	–	–	–	–	–	–	–	29.8	31.7	0.8	
RIO	35.1	29.4	–	30.1	28.9	26.5	26.6	43.9	36.2	–	–	–	–	42.9	33.5	33.8	34.2	0.4	
POP	32.6	25.0	–	28.7	30.9	–	25.5	37.2	34.4	36.9	40.5	–	32.1	44.5	34.6	32.2	33.0	0.4	
BRU	33.4	26.3	–	30.9	28.1	27.6	27.8	39.5	36.2	36.7	40.3	–	32.7	41.9	32.1	33.0	33.3	0.4	
GUA	36.8	27.8	–	33.5	30.8	28.9	31.2	44.2	40.4	39.3	43.1	–	34.6	47.0	34.9	34.8	36.2	0.4	
BRI	36.3	27.1	–	–	–	–	–	–	37.1	–	–	–	–	–	–	–	32.3	34.5	0.7
LIM	37.0	30.6	–	–	31.0	–	32.0	–	–	–	–	–	–	–	–	–	35.8	36.9	0.6
CUL	32.4	27.7	–	28.9	27.4	26.9	26.9	–	35.1	–	42.8	–	–	–	–	–	33.3	33.2	0.5
POT	36.7	29.7	–	31.3	31.2	29.2	29.1	42.8	37.2	–	43.0	–	34.0	–	36.3	34.3	35.7	0.4	
SAN	35.6	29.1	–	34.0	33.2	–	30.9	–	–	–	–	–	–	49.1	37.3	38.4	37.3	0.5	
MPR	32.2	26.4	–	–	30.1	30.5	28.5	39.4	36.5	36.5	42.0	–	–	43.6	–	32.6	33.9	0.4	
STA	34.2	27.8	–	30.5	29.9	28.3	29.5	39.6	35.1	–	42.4	–	32.5	–	33.0	34.3	34.2	0.4	
BYF	32.2	25.0	–	–	–	27.5	25.4	–	34.8	–	40.2	–	–	42.8	31.9	33.6	32.5	0.5	
MEL	34.7	–	–	–	32.3	–	29.6	38.3	38.7	38.8	–	–	–	46.6	36.1	34.4	35.5	0.5	
MAR	–	26.9	–	31.9	–	–	–	–	–	35.6	38.5	–	–	–	–	–	33.3	0.7	
PAL	–	–	–	–	32.9	29.6	–	–	39.2	38.1	40.6	–	–	48.8	–	–	36.0	0.6	
CAB	–	–	–	–	–	–	–	–	–	36.4	–	–	–	–	–	–	33.6	1.4	
MAN	–	–	–	–	31.2	–	–	–	–	36.8	–	–	–	–	–	–	34.8	1.0	
CAY	–	–	–	–	–	–	–	39.6	–	37.7	42.1	–	–	–	–	–	34.7	0.8	
BUR	–	24.9	–	28.5	–	–	–	–	37.6	34.5	40.0	–	32.2	–	–	–	32.8	0.6	
BAT	–	–	–	–	–	–	–	–	–	35.0	–	–	–	–	–	–	32.2	1.4	
AND	–	–	–	33.2	29.4	31.8	–	34.1	39.2	–	–	–	29.7	47.9	–	–	34.5	0.5	
Corr. mean	34.1	27.2	–	30.7	29.7	28.2	28.2	39.4	36.8	36.9	41.4	–	32.8	44.9	34.1	33.4			
s.e.	0.4	0.4	–	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	–	0.5	0.4	0.4	0.4			
s.d.	1.3	0.7	–	1.2	0.9	0.9	1.1	1.3	1.1	0.9	1.2	–	1.0	0.8	0.8	1.3			
F.pr.	***	***	–	*	***	***	***	***	***	**	NS	–	NS	***	***	*			

Table 11. Provenance–locality mean tree stem straightness (index) for 25 provenances of *Pinus caribaea* at 15 localities.

Prov	BFR	SPO	HBG	CPN	JRI	LDA	NBU	BTH	ANO	KBI	MRI	RVU	CTI	MEL	BBM	CDL	Corr. mean	s.e.
KUA	36	36	51	–	–	–	32	–	–	30	29	–	28	–	35	40	33.9	1.3
KAR	33	35	37	57	36	–	33	–	34	–	–	–	–	–	29	37	32.1	1.3
ALA	33	40	39	53	37	28	34	42	37	29	28	–	27	37	30	38	32.7	1.0
PIN	33	–	–	–	–	–	39	–	–	–	–	–	–	–	–	42	35.2	2.3
RIO	33	31	40	45	34	28	34	38	34	–	–	–	–	35	29	35	30.2	1.1
POP	30	33	46	41	31	–	31	36	32	26	25	–	26	38	27	36	29.4	1.0
BRU	35	33	41	43	36	28	33	38	33	29	26	–	28	37	28	38	31.0	1.0
GUA	30	34	37	41	35	26	29	37	33	26	26	–	25	36	29	34	29.1	1.0
BRI	26	37	–	–	–	–	–	–	34	–	–	–	–	–	–	37	30.3	2.0
LIM	22	35	43	–	37	–	30	–	–	–	–	–	–	–	–	37	29.2	1.6
CUL	27	32	38	33	33	28	31	–	32	–	24	–	–	–	–	33	27.6	1.2
POT	27	29	37	30	31	24	27	34	29	–	23	–	23	–	25	29	25.4	1.1
SAN	28	29	–	34	31	–	32	–	–	–	–	–	–	31	27	29	26.2	1.4
MPR	30	32	–	–	33	26	32	38	37	28	26	–	–	38	–	35	30.2	1.2
STA	27	37	56	49	34	29	31	39	34	–	27	–	26	–	28	37	32.0	1.1
BYF	43	36	50	–	–	32	39	–	38	–	31	–	29	48	35	52	37.5	1.2
MEL	39	–	–	–	33	–	33	37	36	29	–	–	–	36	30	41	32.0	1.3
MAR	–	37	–	43	–	–	–	–	–	35	35	–	–	–	–	–	35.6	2.0
PAL	–	–	–	–	38	33	–	–	42	32	34	–	–	53	–	–	38.3	1.6
CAB	–	–	–	–	–	–	–	–	–	37	–	–	–	–	–	–	39.7	4.0
MAN	–	–	–	–	40	–	–	–	–	38	–	–	–	–	–	–	38.7	2.8
CAY	–	–	–	–	–	–	–	58	–	38	34	–	–	–	–	–	42.8	2.3
BUR	–	39	–	48	–	–	–	–	43	41	35	–	40	–	–	–	40.0	1.6
BAT	–	–	–	–	–	–	–	–	–	36	–	–	–	–	–	–	38.7	4.0
AND	–	–	75	43	38	27	–	54	38	–	–	–	34	41	–	–	38.9	1.4
Corr. mean	33.9	36.6	47.4	45.0	36.8	29.5	35.1	42.3	36.6	30.7	29.0	–	29.1	40.2	31.8	39.7		
s.e.	1.0	1.0	1.1	1.1	1.0	1.2	1.0	1.2	1.0	1.1	1.1	–	1.3	1.2	1.2	1.0		
s.d.	1.5	1.4	4.6	4.8	1.1	1.2	1.5	1.8	1.4	1.4	0.9	–	1.2	2.4	1.2	1.8		
F.pr.	***	***	***	**	***	***	***	***	***	***	***	–	***	***	***	***		

Table 12. Provenance–locality mean percentage of trees with stem lean greater than 2.5° for 25 provenances of *Pinus caribaea* at 16 localities.

Prov	BFR	SPO	HBG	CPN	JRI	LDA	NBU	BTH	ANO	KBI	MRI	RVU	CTI	MEL	BBM	CDL	Corr. mean	s.e.
KUA	19.7	16.0	2.9	–	–	–	17.1	–	–	10.8	30.4	–	10.0	–	37.0	7.6	12.7	1.2
KAR	31.6	26.4	14.5	3.1	8.1	–	13.3	–	10.9	–	–	–	–	–	35.4	15.6	15.3	1.4
ALA	24.3	28.4	0	7.6	14.5	23.6	2.6	11.1	4.8	11.7	24.7	2.5	26.0	3.1	38.0	8.0	13.9	1.0
PIN	24.7	–	–	–	–	–	5.1	–	–	–	–	–	–	–	–	10.3	11.0	1.9
RIO	30.0	31.0	2.9	8.9	11.7	21.5	6.4	0	15.3	–	–	0	–	4.7	29.2	13.3	15.3	1.2
POP	36.0	19.2	1.4	7.5	5.8	–	8.3	0	9.2	7.8	32.1	0	14.5	1.6	25.0	7.9	12.9	1.0
BRU	25.3	29.3	0	6.3	7.0	15.3	6.7	6.4	5.3	6.7	30.7	0	5.2	3.2	32.6	4.0	11.9	1.0
GUA	37.5	46.2	0	20.3	13.5	36.6	18.4	11.9	15.2	24.7	43.6	–	34.6	1.6	51.0	19.7	23.9	1.2
BRI	34.2	14.1	–	–	–	–	–	–	4.7	–	–	–	–	–	–	16.4	13.5	1.7
LIM	23.3	15.7	1.4	–	15.1	–	16.9	–	–	–	–	–	–	–	–	33.3	17.6	1.8
CUL	52.5	29.2	4.5	6.2	6.7	36.1	20.5	–	12.3	–	45.1	4.4	–	–	–	21.1	22.3	1.4
POT	45.5	39.5	3.0	1.2	12.3	39.4	17.5	2.4	21.5	–	41.1	3.1	40.7	–	59.2	41.6	25.4	1.3
SAN	22.2	23.2	–	8.5	12.2	–	9.6	–	–	–	–	–	–	1.6	44.0	19.2	15.3	1.5
MPR	20.3	25.7	–	–	4.2	17.4	1.4	0	9.7	8.6	26.0	0	–	4.8	–	14.3	11.8	1.1
STA	32.9	17.3	0	3.8	8.1	20.3	11.5	4.3	12.9	–	29.9	4.1	10.7	–	54.2	29.7	16.1	1.1
BYF	17.9	9.1	1.4	–	–	16.7	7.8	–	4.8	–	21.1	2.4	–	6.7	16.3	5.1	8.7	0.9
MEL	11.8	–	–	–	15.5	–	1.3	7.5	4.9	8.5	–	–	–	3.2	28.9	6.5	9.5	1.2
MAR	–	25.0	–	2.1	–	–	–	–	–	3.9	6.4	–	–	–	–	–	6.8	1.4
PAL	–	–	–	–	5.6	15.2	–	–	8.5	5.4	10.3	0	–	4.9	–	–	8.4	1.4
CAB	–	–	–	–	–	–	–	–	–	5.4	–	–	–	–	–	–	7.7	3.6
MAN	–	–	–	–	5.7	–	–	–	–	1.4	–	–	–	–	–	–	5.4	2.3
CAY	–	–	–	–	–	–	–	2.6	–	4.2	13.3	–	–	–	–	–	6.6	1.7
BUR	–	25.0	–	0	–	–	–	–	3.1	3.9	10.4	–	5.8	–	–	–	7.6	1.3
BAT	–	–	–	–	–	–	–	–	–	5.4	–	–	–	–	–	–	7.7	3.6
AND	–	–	0	10.6	5.7	13.1	–	2.3	0	–	–	0	13.8	1.6	–	–	9.4	1.7
Corr. mean	27.7	23.4	1.3	6.0	9.3	22.1	9.6	4.5	9.1	11.1	27.8	1.5	17.2	3.9	36.2	15.2		
s.e.	1.2	1.2	0.4	0.8	0.8	1.5	0.8	1.0	0.9	1.2	1.5	0.5	1.7	0.8	2.0	1.0		
s.d.	5.0	5.0	1.0	2.7	3.3	4.9	3.3	2.5	3.3	2.9	4.7	1.1	3.9	2.2	6.8	3.9		
F.pr.	***	**	*	N.S.	N.S.	N.S.	*	N.S.	*	N.S.	***	*	**	N.S.	*	***		

Table 13. Provenance–locality mean percentage of trees with forks or multiple stems for 25 provenances of *Pinus caribaea* at 16 localities.

Prov	BFR	SPO	HBG	CPN	JRI	LDA	NBU	BTH	ANO	KBI	MRI	RVU	CTI	MEL	BBM	CDL	Corr. mean	s.e.
KUA	9.2	5.3	1.4	–	–	–	5.7	–	–	5.4	20.3	–	18.0	–	12.8	3.8	8.9	1.2
KAR	17.1	12.5	0	6.4	17.6	–	1.3	–	8.3	–	–	–	–	–	6.2	3.9	8.7	1.1
ALA	6.4	5.3	0	8.5	6.6	22.2	6.5	2.2	3.2	7.8	15.6	10.0	28.0	1.6	16.0	4.0	8.4	0.8
PIN	9.6	–	–	–	–	–	5.1	–	–	–	–	–	–	–	–	10.3	13.1	2.7
RIO	12.5	8.5	2.9	7.3	14.3	15.4	2.6	2.3	8.9	–	–	0	–	3.1	18.6	8.0	8.5	1.0
POP	12.0	31.5	4.3	51.7	42.0	–	29.2	13.3	23.1	26.0	39.7	15.2	34.5	9.8	41.9	15.8	27.3	1.4
BRU	8.9	12.0	1.5	12.1	15.5	13.9	3.3	2.1	5.3	9.3	10.7	19.4	24.1	6.3	11.7	6.7	9.5	0.9
GUA	6.2	9.0	0	11.3	14.9	25.4	2.6	2.4	6.1	14.3	6.4	–	40.4	3.2	24.0	3.9	10.2	0.9
BRI	11.0	33.8	–	–	–	–	–	–	6.8	–	–	–	–	–	–	11.0	17.8	2.4
LIM	13.3	18.6	0	–	20.5	–	7.7	–	–	–	–	0	–	–	–	8.7	12.8	1.7
CUL	12.5	22.2	3.0	24.3	16.0	25.0	12.3	–	3.5	–	28.2	4.4	–	–	–	5.3	14.5	1.2
POT	9.1	27.6	6.1	23.1	27.4	33.8	9.5	0	12.1	–	27.4	6.2	33.3	–	38.0	6.5	17.5	1.2
SAN	4.8	14.5	–	5.5	10.8	–	2.7	–	–	–	–	–	–	1.6	14.0	6.8	7.4	1.1
MPR	16.5	39.2	–	–	33.8	43.5	5.5	4.7	7.9	17.1	16.9	15.4	–	7.9	–	11.7	19.5	1.4
STA	11.0	24.0	4.4	21.8	16.2	26.1	6.4	8.7	7.7	–	20.8	0	21.4	–	14.5	6.8	12.9	1.0
BYF	10.3	28.6	2.8	–	–	27.8	14.3	–	21.9	–	19.7	2.4	–	20.0	14.3	7.7	17.1	1.4
MEL	6.6	–	–	–	16.9	–	5.3	10.0	4.8	5.6	–	–	–	3.2	13.1	5.2	9.4	1.3
MAR	–	27.1	–	33.8	–	–	–	–	–	5.3	9.0	–	–	–	–	–	11.9	1.8
PAL	–	–	–	–	21.1	31.8	–	–	4.9	10.8	11.5	0	–	11.2	–	–	13.1	1.5
CAB	–	–	–	–	–	–	–	–	–	6.8	–	–	–	–	–	–	8.4	3.5
MAN	–	–	–	–	11.7	–	–	–	–	4.2	–	–	–	–	–	–	6.9	1.9
CAY	–	–	–	–	–	–	–	0	–	4.2	14.7	–	–	–	–	–	8.2	2.1
BUR	–	17.2	–	15.9	–	–	–	–	12.5	7.8	3.9	–	11.7	–	–	–	8.2	1.2
BAT	–	–	–	–	–	–	–	–	–	4.1	–	–	–	–	–	–	5.1	2.9
AND	–	–	0	34.5	15.7	21.3	–	14.0	7.5	–	–	5.1	22.4	12.7	–	–	13.2	1.5
Corr. mean	10.2	19.5	2.0	19.7	19.4	25.4	7.5	5.3	8.7	10.8	16.8	5.7	25.9	7.2	20.0	7.2		
s.e.	0.8	1.1	0.5	1.4	1.2	1.6	0.8	1.0	0.9	1.1	1.2	1.0	2.0	1.0	1.7	0.7		
s.d.	3.3	4.5	1.3	4.5	4.2	5.1	2.9	2.9	3.4	3.2	4.1	3.0	5.8	3.0	5.3	2.9		
F.pr.	N.S.	***	**	***	***	N.S.	**	N.S.	**	N.S.	**	**	N.S.	*	***	N.S.		

Table 14. Provenance–locality mean tree values of the mean number of branches per whorl for 25 provenances of *Pinus caribaea* at 16 localities.

Prov	BFR	SPO	HBG	CPN	JRI	LDA	NBU	BTH	ANO	KBI	MRI	RVU	CTI	MEL	BBM	CDL	Corr. mean	s.e.
KUA	3.18	3.37	3.18	–	–	–	3.43	–	–	3.66	3.37	–	3.64	–	3.55	3.25	3.21	.05
KAR	3.26	3.48	3.23	3.04	2.92	–	3.94	–	2.74	–	–	–	–	–	3.68	3.22	3.33	.05
ALA	3.31	3.69	3.26	3.17	2.90	3.41	3.80	3.43	2.81	3.63	3.32	2.65	3.55	3.27	3.50	3.32	3.31	.04
PIN	3.22	–	–	–	–	–	3.86	–	–	–	–	–	–	–	–	–	3.39	.09
RIO	3.10	3.43	3.11	3.19	3.02	3.53	3.82	3.08	2.65	–	–	2.82	–	3.25	3.27	3.29	3.27	.04
POP	3.27	3.43	3.41	3.37	2.80	–	3.44	3.21	2.78	3.65	3.41	2.86	3.56	3.18	3.83	3.21	3.30	.04
BRU	3.25	3.45	3.30	2.82	2.75	3.34	3.66	2.96	2.53	3.61	3.47	2.94	3.68	3.11	3.68	3.07	3.23	.04
GUA	3.50	3.73	3.15	3.15	3.26	3.93	4.22	3.38	2.86	4.10	3.81	–	3.66	3.47	4.14	3.50	3.56	.04
BRI	3.31	3.46	–	–	–	–	–	–	3.05	–	–	–	–	–	–	–	3.61	.08
LIM	3.11	3.62	3.38	–	2.97	–	3.95	–	–	–	–	2.95	–	–	–	3.26	3.38	.06
CUL	3.39	3.56	3.42	3.06	3.20	3.48	3.89	–	2.81	–	3.51	2.97	–	–	–	3.32	3.41	.05
POT	3.20	3.52	3.27	3.00	2.77	3.51	4.95	3.33	2.81	–	3.42	2.83	3.52	–	3.65	3.29	3.39	.04
SAN	2.95	3.35	–	2.85	2.76	–	3.39	–	–	–	–	–	–	2.93	3.34	2.85	3.04	.06
MPR	3.19	3.47	–	–	2.88	3.46	3.67	3.27	2.92	3.40	3.32	3.13	–	3.28	–	3.33	3.30	.05
STA	3.25	3.59	3.32	2.95	3.00	3.79	4.14	3.44	3.14	–	3.83	3.04	4.21	–	4.07	3.33	3.53	.04
BYF	3.29	3.52	3.35	–	–	3.55	3.81	–	3.03	–	3.67	3.09	–	3.36	3.84	3.59	3.45	.05
MEL	3.15	–	–	–	2.94	–	3.82	3.23	3.63	3.62	–	–	–	3.34	3.77	3.27	3.31	.05
MAR	–	3.66	–	3.15	–	–	–	–	–	4.14	4.07	–	–	–	–	–	3.65	.08
PAL	–	–	–	–	2.98	3.40	–	–	3.04	3.81	3.71	3.30	–	3.30	–	–	3.46	.06
CAB	–	–	–	–	–	–	–	–	–	3.79	–	–	–	–	–	–	3.42	.17
MAN	–	–	–	–	3.13	–	–	–	–	3.94	–	–	–	–	–	–	3.55	.12
CAY	–	–	–	–	–	–	–	3.07	–	3.98	3.78	–	–	–	–	–	3.46	.10
BUR	–	3.69	–	3.08	–	–	–	–	3.15	3.96	3.98	–	4.26	–	–	–	3.65	.07
BAT	–	–	–	–	–	–	–	–	–	4.00	–	–	–	–	–	–	3.63	.17
AND	–	–	3.02	2.96	2.84	3.31	–	3.20	2.70	–	–	2.69	3.50	3.18	–	–	3.20	.05
Corr. mean	3.28	3.54	3.31	3.08	2.99	3.54	3.92	3.28	2.86	3.77	3.59	2.98	3.75	3.33	3.76	3.35		
s.e.	.04	.04	.05	.05	.04	.05	.04	.05	.04	.04	.04	.05	.06	.05	.05	.04		
s.d.	.10	.09	.11	.11	.10	.09	.12	.14	.11	.11	.11	.13	.11	.11	.16	.09		
F.pr.	N.S.	N.S.	N.S.	*	***	***	***	N.S.	***	***	***	N.S.	***	N.S.	**	***		

Table 15. Provenance–locality mean tree value of number of whorls (between 1 m and 6 m above ground) for 25 provenances of *Pinus caribaea* at 16 localities.

Prov	BFR	SPO	HBG	CPN	JRI	LDA	NBU	BTH	ANO	KBI	MRI	RVU	CTI	MEL	BBM	CDL	Corr. mean	s.e.
KUA	9.7	9.1	10.0	–	–	–	8.2	–	–	8.7	8.2	–	7.5	–	8.7	8.6	9.3	0.3
KAR	8.7	9.4	9.9	10.9	7.4	–	9.0	–	10.6	–	–	–	–	–	6.9	8.4	8.7	0.3
ALA	9.1	9.7	9.3	8.9	6.7	7.2	8.3	12.2	9.7	7.1	6.7	7.8	5.5	9.2	7.1	8.4	8.3	0.2
PIN	7.8	–	–	–	–	–	8.3	–	–	–	–	–	–	–	–	7.7	7.8	0.5
RIO	7.8	10.1	10.4	11.6	6.9	8.0	7.4	11.9	9.8	–	–	8.3	–	10.2	6.4	8.9	8.7	0.2
POP	8.6	9.5	8.6	10.0	7.8	–	7.2	10.7	7.9	7.7	7.4	8.0	7.0	10.2	6.5	10.1	8.4	0.2
BRU	9.7	8.6	10.1	10.9	6.0	7.3	8.3	11.0	9.5	7.7	7.3	8.7	4.7	8.4	7.0	7.2	8.3	0.2
GUA	9.9	10.0	8.6	14.2	9.3	9.6	10.2	11.4	11.6	8.5	9.4	–	6.8	12.1	8.5	10.6	10.0	0.2
BRI	11.9	11.8	–	–	–	–	–	–	12.4	–	–	–	–	–	–	11.3	11.3	0.4
LIM	11.0	11.5	10.3	–	10.8	–	12.1	–	–	–	–	12.0	–	–	–	11.7	11.4	0.3
CUL	9.5	10.8	9.2	12.0	9.2	9.1	9.5	–	11.2	–	7.7	9.7	–	–	–	10.4	9.7	0.3
POT	10.2	10.9	9.5	12.3	9.2	9.0	9.7	12.5	11.5	–	9.0	9.8	7.5	–	8.9	10.7	10.1	0.2
SAN	8.5	9.8	–	12.6	8.6	–	9.9	–	–	–	–	–	–	10.4	7.5	8.8	9.1	0.3
MPR	8.6	10.0	–	–	7.7	7.9	8.0	11.0	10.2	7.7	7.8	8.8	–	10.2	–	9.4	8.8	0.2
STA	10.7	11.4	9.7	13.6	9.4	9.3	11.3	12.5	11.6	–	8.8	8.9	8.5	–	9.2	10.6	10.4	0.2
BYF	11.0	9.4	10.3	–	–	8.4	9.2	–	9.7	–	9.0	8.7	–	12.3	9.1	11.1	9.9	0.3
MEL	10.9	–	–	–	8.8	–	10.2	9.9	11.5	9.6	–	–	–	11.9	8.6	10.4	10.0	0.3
MAR	–	16.5	–	18.3	–	–	–	–	–	13.8	13.0	–	–	–	–	–	15.2	0.4
PAL	–	–	–	–	13.9	14.5	–	–	17.1	13.1	12.7	12.6	–	17.5	–	–	14.8	0.3
CAB	–	–	–	–	–	–	–	–	–	13.4	–	–	–	–	–	–	14.6	0.9
MAN	–	–	–	–	15.4	–	–	–	–	13.4	–	–	–	–	–	–	15.4	0.6
CAY	–	–	–	–	–	–	–	18.7	–	13.7	13.2	–	–	–	–	–	15.3	0.5
BUR	–	16.3	–	18.7	–	–	–	–	16.7	13.4	13.5	–	12.4	–	–	–	15.3	0.4
BAT	–	–	–	–	–	–	–	–	–	13.4	–	–	–	–	–	–	14.6	0.9
AND	–	–	10.4	12.2	13.2	9.7	–	13.6	10.0	–	–	5.8	7.4	12.4	–	–	10.2	0.3
Corr. mean	11.2	11.7	11.2	13.6	10.3	10.2	10.9	13.5	12.2	9.8	9.6	10.2	8.5	12.7	9.6	11.3		
s.e.	.22	.22	.25	.25	.23	.28	.23	.27	.23	.24	.24	.26	.30	.27	.26	.22		
s.d.	.45	.51	.44	.64	.54	.48	.55	.63	.60	.42	.51	.91	.57	.66	.63	.49		
F.pr.	***	***	*	***	***	***	***	***	***	***	***	***	***	***	**	***		

Table 16. Provenance–locality mean tree value of longest internode length (m) for 25 provenances of *Pinus caribaea* at 16 localities.

Prov	BFR	SPO	HBG	CPN	JRI	LDA	NBU	BTH	ANO	KBI	MRI	RVU	CTI	MEL	BBM	CDL	Corr. mean	s.e.
KUA	1.7	1.3	0.6	–	–	–	2.8	–	–	2.1	2.2	–	2.4	–	2.2	1.9	1.8	.13
KAR	1.8	1.5	0.7	1.4	2.1	–	2.9	–	2.4	–	–	–	–	–	3.9	1.9	2.1	.13
ALA	1.8	1.3	0.8	2.4	2.3	2.1	2.8	1.3	3.0	3.1	3.3	1.5	3.8	2.2	2.8	2.3	2.3	.09
PIN	2.3	–	–	–	–	–	2.9	–	–	–	–	–	–	–	–	2.4	2.4	.22
RIO	2.3	1.2	0.9	1.7	2.0	1.9	3.5	1.3	2.5	–	–	1.4	–	1.8	3.0	1.8	2.1	.10
POP	1.6	1.5	0.9	1.8	1.8	–	2.8	2.7	2.5	2.3	2.5	1.5	2.3	1.5	2.5	1.6	2.0	.10
BRU	2.1	1.6	0.8	1.7	2.6	2.2	3.3	2.0	2.6	2.7	3.4	1.0	4.6	2.4	3.3	2.2	2.4	.09
GUA	1.4	1.1	0.7	0.8	1.8	1.5	2.3	1.0	1.3	2.2	1.7	–	2.0	1.2	2.0	1.7	1.5	.10
BRI	0.9	1.1	–	–	–	–	–	–	1.1	–	–	–	–	–	–	–	1.1	.19
LIM	1.1	0.9	0.7	–	1.1	–	0.8	–	–	–	–	1.0	–	–	–	1.0	1.2	.14
CUL	1.5	1.4	0.8	1.3	1.6	1.4	2.7	–	1.7	–	2.1	1.1	–	–	–	1.4	1.7	.11
POT	1.3	1.1	0.9	1.4	1.5	1.6	2.0	1.0	1.5	–	2.3	1.0	2.3	–	1.7	1.4	1.5	.10
SAN	1.7	1.2	–	1.5	1.5	–	2.2	–	–	–	–	–	–	1.3	2.0	2.2	1.7	.14
MPR	1.7	1.4	–	–	2.1	1.5	2.2	2.1	1.6	2.4	2.5	1.5	–	1.8	–	1.7	1.9	.11
STA	1.3	1.0	0.7	0.7	1.6	1.4	2.0	1.6	2.4	–	2.0	1.9	1.6	–	2.1	1.3	1.5	.10
BYF	1.6	2.2	0.9	–	–	1.6	2.3	–	2.0	–	1.9	1.6	–	1.2	2.0	1.3	1.7	.11
MEL	1.1	–	–	–	1.5	–	2.3	2.0	1.6	1.8	–	–	–	1.5	1.9	1.4	1.6	.13
MAR	–	0.8	–	0.9	–	–	–	–	–	0.7	1.0	–	–	–	–	–	0.8	.19
PAL	–	–	–	–	1.0	0.8	–	–	0.6	0.9	1.0	0.4	–	0.6	–	–	0.7	.14
CAB	–	–	–	–	–	–	–	–	–	0.9	–	–	–	–	–	–	0.6	.39
MAN	–	–	–	–	0.8	–	–	–	–	0.8	–	–	–	–	–	–	0.7	.27
CAY	–	–	–	–	–	–	–	0.8	–	0.8	1.2	–	–	–	–	–	0.7	.22
BUR	–	0.9	–	0.9	–	–	–	–	0.6	0.8	0.8	–	0.8	–	–	–	0.6	.16
BAT	–	–	–	–	–	–	–	–	–	0.7	–	–	–	–	–	–	0.4	.39
AND	–	–	0.7	1.5	0.8	1.4	–	1.8	1.9	–	–	1.8	1.8	1.3	–	–	1.6	.13
Corr. mean	1.3	1.1	0.4	1.2	1.4	1.3	2.1	1.3	1.6	1.8	1.9	1.1	2.2	1.2	2.1	1.4		
s.e.	.10	.10	.11	.11	.10	.12	.10	.12	.10	.11	.11	.11	.13	.12	.11	.10		
s.d.	.18	.17	.07	.22	.16	.15	.33	.29	.43	.16	.29	.22	.33	.21	.35	.18		
F.pr.	***	***	NS	***	***	***	***	**	***	***	***	***	***	***	**	***		

Table 17. Provenance–locality mean percentage of trees with fine or fine/medium branches for 25 provenances of *Pinus caribaea* at 16 localities.

Prov	BFR	SPO	HBG	CPN	JRI	LDA	NBU	BTH	ANO	KBI	MRI	RVU	CTI	MEL	BBM	CDL	Corr. mean	s.e.
KUA	60.5	36.0	43.5	–	–	–	21.4	–	–	31.1	29.5	–	24.0	–	39.5	44.3	36.2	1.9
KAR	56.6	44.4	36.8	20.3	29.7	–	22.7	–	30.9	–	–	–	–	–	45.9	36.4	33.7	1.9
ALA	60.3	46.1	38.6	32.9	23.7	27.8	24.7	48.9	41.3	29.2	29.7	40.0	18.4	23.4	34.0	36.0	34.0	1.4
PIN	43.8	–	–	–	–	–	33.3	–	–	–	–	–	–	–	–	32.1	31.2	3.0
RIO	47.5	36.6	30.9	26.6	26.0	30.8	16.7	38.6	34.3	–	–	40.4	–	15.6	35.3	37.3	31.3	1.6
POP	48.0	35.6	31.4	20.0	31.9	–	16.7	41.9	27.7	23.4	23.1	26.1	29.0	11.5	37.5	39.4	30.2	1.5
BRU	48.7	45.3	35.3	16.5	40.8	31.9	31.7	39.1	26.3	20.8	20.5	58.3	31.0	19.0	40.5	33.3	33.5	1.5
GUA	35.4	37.3	13.8	17.2	45.9	50.7	23.7	33.3	39.4	21.3	23.1	–	26.9	19.4	32.7	39.5	31.6	1.5
BRI	41.1	38.0	–	–	–	–	–	–	45.7	–	–	–	–	–	–	42.5	31.8	2.6
LIM	45.0	35.7	30.4	–	32.9	–	26.2	–	–	–	–	37.5	–	–	–	52.2	33.4	2.2
CUL	46.2	33.3	27.3	15.0	24.0	27.8	11.0	–	24.3	–	16.9	28.9	–	–	–	44.7	26.6	1.6
POT	32.5	27.6	16.7	11.4	23.3	36.6	12.7	38.1	13.8	–	24.7	43.8	14.8	–	16.3	36.4	23.7	1.4
SAN	47.6	27.5	–	10.6	9.5	–	23.3	–	–	–	–	–	–	4.8	30.0	38.4	24.2	1.9
MPR	59.5	41.9	–	–	45.1	39.1	20.5	39.5	47.9	27.1	35.5	33.3	–	22.2	–	58.4	39.3	1.7
STA	45.2	52.0	51.5	18.8	37.0	33.3	26.9	32.6	38.7	–	23.4	32.7	44.6	–	27.0	37.8	35.2	1.5
BYF	73.1	54.5	40.8	–	–	45.8	48.1	–	50.8	–	50.0	45.2	–	35.0	57.1	65.4	51.0	1.8
MEL	60.5	–	–	–	39.4	–	48.7	37.5	55.7	36.6	–	–	–	25.8	49.1	51.9	44.8	2.1
MAR	–	59.0	–	50.0	–	–	–	–	–	65.8	66.7	–	–	–	–	–	67.1	2.9
PAL	–	–	–	–	66.2	43.9	–	–	93.2	55.4	47.4	64.3	–	23.0	–	–	59.1	2.4
CAB	–	–	–	–	–	–	–	–	–	68.9	–	–	–	–	–	–	73.9	4.9
MAN	–	–	–	–	52.9	–	–	–	–	60.6	–	–	–	–	–	–	59.1	4.0
CAY	–	–	–	–	–	–	–	73.7	–	63.9	56.0	–	–	–	–	–	66.4	3.4
BUR	–	68.8	–	54.2	–	–	–	–	84.4	58.4	64.9	–	65.4	–	–	–	68.9	2.4
BAT	–	–	–	–	–	–	–	–	–	64.9	–	–	–	–	–	–	70.4	5.1
AND	–	–	47.0	10.9	71.4	27.9	–	46.5	74.9	–	–	43.6	20.7	22.2	–	–	44.0	2.2
Corr. mean	53.7	43.0	37.6	23.8	38.3	36.5	29.2	42.5	43.7	31.0	30.8	41.2	30.5	19.8	40.6	45.4		
s.e.	1.4	1.4	1.6	1.5	1.4	1.7	1.3	2.2	1.6	1.5	1.4	2.2	2.1	1.5	2.0	1.4		
s.d.	5.7	5.7	5.5	4.9	5.3	5.7	5.2	7.3	5.7	5.3	5.1	7.9	5.9	4.9	6.7	5.6		
F.pr.	**	***	**	**	***	*	***	N.S.	***	***	***	N.S.	***	N.S.	*	**		

Table 18. Provenance–locality mean percentage of trees with cones for 25 provenances of *Pinus caribaea* at 13 localities.

Prov	BFR	SPO	HBG	CPN	JRI	LDA	NBU	BTH	ANO	KBI	MRI	RVU	CTI	MEL	BBM	CDL	Corr. mean	s.e.
KUA	1.3	42.7	–	–	–	–	17.1	–	–	0	–	–	–	–	0	7.6	10.8	1.4
KAR	0	25.0	–	20.3	33.8	–	14.7	–	5.1	–	–	–	–	–	4.2	7.8	10.9	1.1
ALA	0	38.2	–	24.1	34.2	9.7	20.8	2.2	1.6	1.3	–	0	–	18.8	0	10.7	12.5	1.0
PIN	2.7	–	–	–	–	–	35.9	–	–	–	–	–	–	–	–	15.4	14.5	2.0
RIO	2.5	56.3	–	35.4	32.5	10.8	30.8	0	5.8	–	–	6.4	–	7.8	0	12.0	15.7	1.1
POP	13.3	28.8	–	22.5	30.4	–	41.7	28.9	23.1	10.4	–	17.4	–	29.5	4.2	42.1	24.1	1.4
BRU	5.1	53.3	–	20.3	33.8	20.8	28.3	0	3.5	0	–	0	–	15.9	0	16.0	15.5	1.1
GUA	1.2	28.4	–	6.2	21.6	2.8	14.5	2.4	0	0	–	–	–	4.8	0	2.6	6.5	0.8
BRI	20.5	50.7	–	–	–	–	–	–	22.8	–	–	–	–	–	–	50.7	31.9	2.4
LIM	26.7	22.9	–	–	28.8	–	63.1	–	–	–	–	0	–	–	–	39.1	23.0	1.8
CUL	55.0	58.3	–	51.2	58.7	79.2	76.7	–	40.4	–	–	17.8	–	–	–	76.3	47.8	1.7
POT	23.4	48.7	–	31.2	35.6	40.8	39.7	7.1	16.9	–	–	3.1	–	–	14.3	28.6	24.3	1.4
SAN	0	46.4	–	21.3	25.7	–	20.5	–	–	–	–	–	–	11.1	0	5.5	12.5	1.2
MPR	12.7	58.1	–	–	59.2	34.8	57.5	23.3	22.6	7.1	–	5.1	–	19.0	–	35.1	28.3	1.5
STA	34.2	41.3	–	30.0	56.8	58.0	76.9	21.7	46.8	–	–	2.0	–	–	25.0	55.4	37.1	1.5
BYF	11.5	55.8	–	–	–	50.0	54.5	–	34.9	–	–	0	–	57.7	12.2	34.6	32.4	1.5
MEL	6.6	–	–	–	32.4	–	22.4	17.5	6.6	0	–	–	–	8.1	0	3.9	11.3	1.3
MAR	–	0	–	0	–	–	–	–	–	2.6	–	–	–	–	–	–	1.1	0.8
PAL	–	–	–	–	9.9	18.2	–	–	0	2.7	–	0	–	1.6	–	–	6.4	1.3
CAB	–	–	–	–	–	–	–	–	0	–	–	–	–	–	–	–	0	0.3
MAN	–	–	–	–	10.0	–	–	–	–	0	–	–	–	–	–	–	4.3	1.6
CAY	–	–	–	–	–	–	–	2.6	–	0	–	–	–	–	–	–	3.6	3.5
BUR	–	1.6	–	2.1	–	–	–	–	1.6	0	–	–	–	–	–	–	1.3	0.7
BAT	–	–	–	–	–	–	–	–	–	0	–	–	–	–	–	–	0	0.3
AND	–	–	–	6.4	5.7	4.9	–	0	0	–	–	5.1	–	9.5	–	–	4.5	1.0
Corr. mean	11.1	36.9	–	23.3	33.2	26.8	35.0	11.1	13.5	4.4	–	3.8	–	20.5	5.7	22.8		
s.e.	0.8	1.3	–	1.4	1.3	1.5	1.3	1.5	1.0	1.0	–	0.7	–	1.6	1.0	1.0		
s.d.	2.9	5.1	–	4.1	5.0	4.5	5.2	3.3	3.4	3.3	–	2.2	–	4.1	1.8	3.9		
F.pr.	***	***	–	***	***	***	***	***	***	***	–	***	–	***	***	***		

Table 19. Provenance–locality mean tree pilodyn reading (mm) for 25 provenances of *Pinus caribaea* at 5 localities.

Prov	BFR	SPO	HBG	CPN	JRI	LDA	NBU	BTH	ANO	KBI	MRI	RVU	CTI	MEL	BBM	CDL	Corr. mean	s.e.
KUA	-	11.8	-	-	-	-	12.3	-	-	14.8	12.9	-	-	-	-	-	13.2	.27
KAR	-	11.6	-	-	-	-	11.7	-	-	-	-	-	-	-	-	-	13.3	.39
ALA	-	12.4	-	-	-	15.0	12.2	-	-	16.3	13.7	-	-	-	-	-	13.9	.24
PIN	-	-	-	-	-	-	10.9	-	-	-	-	-	-	-	-	-	12.7	.56
RIO	-	12.2	-	-	-	14.0	11.6	-	-	-	-	-	-	-	-	-	13.4	.32
POP	-	11.2	-	-	-	-	11.3	-	-	14.7	14.0	-	-	-	-	-	13.0	.27
BRU	-	12.8	-	-	-	14.8	11.6	-	-	15.3	14.0	-	-	-	-	-	13.7	.24
GUA	-	11.7	-	-	-	14.0	11.0	-	-	13.7	12.8	-	-	-	-	-	12.6	.24
BRI	-	11.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13.3	.55
LIM	-	11.6	-	-	-	-	10.6	-	-	-	-	-	-	-	-	-	12.8	.39
CUL	-	12.6	-	-	-	15.0	11.6	-	-	-	14.7	-	-	-	-	-	13.9	.27
POT	-	11.6	-	-	-	13.7	10.8	-	-	-	13.4	-	-	-	-	-	12.8	.27
SAN	-	11.9	-	-	-	-	11.6	-	-	-	-	-	-	-	-	-	13.4	.39
MPR	-	11.4	-	-	-	14.3	10.6	-	-	15.0	13.6	-	-	-	-	-	13.0	.24
STA	-	11.1	-	-	-	14.0	11.0	-	-	-	14.0	-	-	-	-	-	12.9	.27
BYF	-	11.2	-	-	-	13.3	10.6	-	-	-	13.0	-	-	-	-	-	12.4	.27
MEL	-	-	-	-	-	-	11.4	-	-	14.2	-	-	-	-	-	-	12.9	.39
MAR	-	9.5	-	-	-	-	-	-	-	14.0	14.1	-	-	-	-	-	12.3	.32
PAL	-	-	-	-	-	12.6	-	-	-	13.4	12.9	-	-	-	-	-	11.8	.32
CAB	-	-	-	-	-	-	-	-	-	14.1	-	-	-	-	-	-	12.4	.56
MAN	-	-	-	-	-	-	-	-	-	13.4	-	-	-	-	-	-	11.7	.56
CAY	-	-	-	-	-	-	-	-	-	13.8	14.0	-	-	-	-	-	12.7	.39
BUR	-	9.8	-	-	-	-	-	-	-	14.5	13.3	-	-	-	-	-	12.3	.32
BAT	-	-	-	-	-	-	-	-	-	13.9	-	-	-	-	-	-	12.2	.56
AND	-	-	-	-	-	11.4	-	-	-	-	-	-	-	-	-	-	10.4	.56
Corr. mean	-	11.2	-	-	-	13.8	10.9	-	-	14.4	13.5	-	-	-	-	-	-	-
s.e.	-	.15	-	-	-	.19	.15	-	-	.17	.16	-	-	-	-	-	-	-
s.d.	-	1.3	-	-	-	1.3	1.4	-	-	1.4	1.9	-	-	-	-	-	-	-
F.pr.	-	***	-	-	-	***	*	-	-	***	**	-	-	-	-	-	-	-

Table 20. Provenance–locality mean tree basic density (g cm^{-3}) for 25 provenances of *Pinus caribaea* at 13 localities.

Prov	BFR	SPO	HBG	CPN	JRI	LDA	NBU	BTH	ANO	KBI	MRI	RVU	CTI	MEL	BBM	CDL	Corr. mean	s.e.
KUA	.422	.400	-	-	-	-	.454	-	-	.379	.384	-	.386	-	.403	.395	.405	.004
KAR	.413	.441	-	-	.385	-	.447	-	.401	-	-	-	-	-	.386	.389	.401	.005
ALA	.397	.410	-	-	.385	.393	.433	.373	.391	.359	.371	-	.360	.404	.392	.390	.389	.003
PIN	.397	-	-	-	-	-	.445	-	-	-	-	-	-	-	-	.395	.397	.007
RIO	.395	.436	-	-	.403	.398	.450	.376	.388	-	-	-	-	.412	.385	.394	.395	.004
POP	.405	.419	-	-	.394	-	.417	.400	.408	.372	.363	-	.374	.402	.400	.404	.398	.003
BRU	.397	.439	-	-	.370	.415	.439	.370	.379	.388	.380	-	.376	.408	.397	.381	.395	.003
GUA	.423	.426	-	-	.385	.427	.477	.411	.406	.395	.387	-	.370	.460	.406	.408	.414	.003
BRI	.404	.439	-	-	-	-	-	-	.389	-	-	-	-	-	-	-	.399	.006
LIM	.421	.442	-	-	.393	-	.446	-	-	-	-	-	-	-	-	.401	.408	.005
CUL	.402	.404	-	-	.360	.415	.431	-	.392	-	.364	-	-	-	-	.389	.388	.004
POT	.415	.437	-	-	.408	.444	.427	.404	.422	-	.391	-	.379	-	.411	.406	.413	.004
SAN	.411	.447	-	-	.385	-	.445	-	-	-	-	-	-	.420	.385	.390	.401	.005
MPR	.391	.426	-	-	.392	.411	.436	.386	.399	.377	.368	-	-	.410	-	.398	.396	.004
STA	.423	.447	-	-	.388	.419	.454	.391	.398	-	.387	-	.367	-	.389	.373	.403	.004
BYF	.401	.434	-	-	-	.415	.442	-	.389	-	.366	-	-	.418	.385	.395	.396	.004
MEL	.415	-	-	-	.388	-	.439	.374	.383	.386	-	-	-	.423	.393	.410	.400	.004
MAR	-	.448	-	-	-	-	-	-	-	.387	.365	-	-	-	-	-	.407	.007
PAL	-	-	-	-	.404	.446	-	-	.415	.383	.369	-	-	.451	-	-	.415	.005
CAB	-	-	-	-	-	-	-	-	.391	-	-	-	-	-	-	-	.412	.012
MAN	-	-	-	-	.419	-	-	-	-	.401	-	-	-	-	-	-	.427	.009
CAY	-	-	-	-	-	-	-	.407	-	.395	.359	-	-	-	-	-	.403	.009
BUR	-	.441	-	-	-	-	-	-	.418	.382	.355	-	.372	-	-	-	.407	.005
BAT	-	-	-	-	-	-	-	-	-	.385	-	-	-	-	-	-	.406	.012
AND	-	-	-	-	.362	.452	-	.347	.377	-	-	-	.349	.425	-	-	.388	.005
Corr. mean	.410	.433	-	-	.389	.425	.445	.387	.400	.382	.373	-	.372	.425	.396	.398	-	-
s.e.	.003	.003	-	-	.003	.004	.003	.004	.003	.003	.003	-	.004	.004	.004	.003	-	-
s.d.	.015	.022	-	-	.019	.020	.017	.024	.017	.013	.015	-	.015	.021	.012	.015	-	-
F.pr.	N.S.	N.S.	-	-	*	*	*	N.S.	N.S.	N.S.	N.S.	-	N.S.	*	N.S.	N.S.	-	-

Table 21. Provenance–locality mean percentage of trees with α -pinene + β -pinene > 80% for 25 provenances of *Pinus caribaea* at 3 localities.

Prov	BFR	SPO	HBG	CPN	JRI	LDA	NBU	BTH	ANO	KBI	MRI	RVU	CTI	MEL	BBM	CDL	Corr. mean	s.e.
KUA	-	-	-	-	-	-	-	-	-	-	33.3	-	-	-	-	-	30.3	12.4
KAR	-	-	-	-	33.3	-	-	-	-	-	-	-	-	-	-	-	24.5	7.9
ALA	-	-	-	-	65.2	-	-	-	-	-	27.3	-	-	35.0	-	-	48.6	6.6
PIN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RIO	-	-	-	-	55.0	-	-	-	-	-	-	-	-	35.0	-	-	50.5	8.6
POP	-	-	-	-	90.0	-	-	-	-	-	33.3	-	-	25.0	-	-	58.7	7.1
BRU	-	-	-	-	56.5	-	-	-	-	-	28.6	-	-	50.0	-	-	53.0	6.9
GUA	-	-	-	-	26.1	-	-	-	-	-	23.1	-	-	5.0	-	-	18.7	5.2
BRI	-	-	-	-	-	-	-	-	-	-	-	-	-	75.0	-	-	87.5	5.5
LIM	-	-	-	-	65.2	-	-	-	-	-	-	-	-	-	-	-	52.6	10.3
CUL	-	-	-	-	81.0	-	-	-	-	-	71.4	-	-	-	-	-	68.0	8.1
POT	-	-	-	-	36.0	-	-	-	-	-	33.3	-	-	-	-	-	27.6	6.9
SAN	-	-	-	-	60.0	-	-	-	-	-	88.9	-	-	25.0	-	-	54.7	6.9
MPR	-	-	-	-	60.9	-	-	-	-	-	69.2	-	-	30.0	-	-	53.9	6.4
STA	-	-	-	-	77.3	-	-	-	-	-	63.6	-	-	-	-	-	62.7	8.4
BYF	-	-	-	-	-	-	-	-	-	-	100.0	-	-	45.0	-	-	68.9	9.0
MEL	-	-	-	-	58.8	-	-	-	-	-	88.9	-	-	30.0	-	-	57.0	7.1
MAR	-	-	-	-	-	-	-	-	-	-	17.6	-	-	-	-	-	16.2	8.6
PAL	-	-	-	-	60.0	-	-	-	-	-	44.4	-	-	0.0	-	-	37.3	5.9
CAB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MAN	-	-	-	-	47.8	-	-	-	-	-	-	-	-	-	-	-	36.5	9.3
CAY	-	-	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	0.0	0.3
BUR	-	-	-	-	-	-	-	-	-	-	58.8	-	-	-	-	-	53.4	11.6
BAT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AND	-	-	-	-	4.2	-	-	-	-	-	-	-	-	0.0	-	-	2.4	2.4
Corr. mean	-	-	-	-	56.2	-	-	-	-	-	49.9	-	-	25.8	-	-	-	-
s.e.	-	-	-	-	2.6	-	-	-	-	-	3.9	-	-	2.9	-	-	-	-
s.d.	-	-	-	-	9.4	-	-	-	-	-	12.0	-	-	8.0	-	-	-	-
F.pr.	-	-	-	-	***	-	-	-	-	-	N.S.	-	-	**	-	-	-	-

Table 22. Provenance–locality mean tree log ratio of (α -pinene + β -pinene + β -phellandrene) to Δ -3-carene for 25 provenances of *Pinus caribaea* at 3 localities.

Prov	BFR	SPO	HBG	CPN	JRI	LDA	NBU	BTH	ANO	KBI	MRI	RVU	CTI	MEL	BBM	CDL	Corr. mean	s.e.
KUA	-	-	-	-	-	-	-	-	-	-	3.06	-	-	-	-	-	2.85	.16
KAR	-	-	-	-	3.25	-	-	-	-	-	-	-	-	-	-	-	3.24	.16
ALA	-	-	-	-	4.12	-	-	-	-	-	3.98	-	-	4.01	-	-	4.04	.09
PIN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RIO	-	-	-	-	4.22	-	-	-	-	-	-	-	-	4.07	-	-	4.25	.11
POP	-	-	-	-	4.31	-	-	-	-	-	4.16	-	-	3.88	-	-	4.12	.09
BRU	-	-	-	-	3.95	-	-	-	-	-	4.33	-	-	3.98	-	-	4.09	.09
GUA	-	-	-	-	4.06	-	-	-	-	-	4.16	-	-	3.94	-	-	4.05	.09
BRI	-	-	-	-	-	-	-	-	-	-	-	-	-	4.92	-	-	5.14	.16
LIM	-	-	-	-	4.29	-	-	-	-	-	-	-	-	-	-	-	4.28	.16
CUL	-	-	-	-	4.33	-	-	-	-	-	4.31	-	-	-	-	-	4.21	.11
POT	-	-	-	-	4.13	-	-	-	-	-	4.40	-	-	-	-	-	4.16	.11
SAN	-	-	-	-	4.24	-	-	-	-	-	4.50	-	-	3.95	-	-	4.23	.09
MPR	-	-	-	-	4.18	-	-	-	-	-	4.34	-	-	4.02	-	-	4.18	.09
STA	-	-	-	-	3.96	-	-	-	-	-	4.08	-	-	-	-	-	3.92	.11
BYF	-	-	-	-	-	-	-	-	-	-	4.95	-	-	4.02	-	-	4.49	.11
MEL	-	-	-	-	4.27	-	-	-	-	-	4.56	-	-	3.94	-	-	4.26	.09
MAR	-	-	-	-	-	-	-	-	-	-	4.13	-	-	-	-	-	3.93	.16
PAL	-	-	-	-	3.75	-	-	-	-	-	4.30	-	-	3.64	-	-	3.90	.09
CAB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MAN	-	-	-	-	3.76	-	-	-	-	-	-	-	-	-	-	-	3.74	.16
CAY	-	-	-	-	-	-	-	-	-	-	4.05	-	-	-	-	-	3.84	.16
BUR	-	-	-	-	-	-	-	-	-	-	4.33	-	-	-	-	-	4.12	.16
BAT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AND	-	-	-	-	3.68	-	-	-	-	-	-	-	-	3.37	-	-	3.63	.11
Corr. mean	-	-	-	-	4.04	-	-	-	-	-	4.23	-	-	3.81	-	-	-	-
s.e.	-	-	-	-	.04	-	-	-	-	-	.04	-	-	.05	-	-	-	-
s.d.	-	-	-	-	.12	-	-	-	-	-	.18	-	-	.43	-	-	-	-
F.pr.	-	-	-	-	***	-	-	-	-	-	**	-	-	*	-	-	-	-

Table 23. Provenance–locality mean percentage survival for 24 provenances of *Pinus oocarpa* / *P. patula* ssp. *tecunumanii* at 13 localities.

Prov	MEL	AGU	LDA	SPO	CCO	NBO	TUR	ANO	WIL	KBI	HBG	CPN	NDU	Corr. mean	s.e.
CAM	–	87.5	78.1	83.8	88.8	62.0	62.5	94.3	83.8	95.0	87.5	70.8	68.8	79.6	1.6
SUL	90.0	–	–	–	–	–	–	–	–	–	–	–	–	81.5	9.1
ZAP	86.7	95.3	83.3	81.2	85.0	64.0	71.9	68.6	88.8	–	83.3	–	75.0	79.8	1.6
MAR	86.7	85.9	–	81.2	–	70.0	–	–	–	–	–	–	65.6	78.2	2.6
CAN	–	–	56.2	–	82.5	–	–	–	76.2	92.5	70.8	75.0	78.1	74.0	2.4
LIM	–	89.1	–	76.2	–	60.0	–	–	–	–	–	–	–	75.9	3.2
CON	96.7	–	65.6	82.5	–	70.0	73.4	74.3	–	–	85.4	–	71.9	80.1	1.9
MQT	–	–	–	–	–	–	–	–	–	87.5	–	56.2	87.5	76.1	3.7
AGF	–	–	–	76.2	–	–	–	74.3	92.5	–	–	–	–	78.4	3.2
PUE	–	93.8	83.3	–	–	–	–	–	–	–	–	–	–	86.4	3.7
JUN	93.3	–	75.0	–	–	56.0	–	80.0	81.2	–	81.2	–	53.1	73.8	2.6
BON	93.3	–	87.5	–	–	66.7	70.3	–	–	–	93.8	–	78.1	82.8	2.3
BUC	70.0	98.4	65.6	80.0	–	56.0	85.9	80.0	–	90.0	83.3	–	75.0	79.1	1.8
ANG	–	89.1	59.4	75.0	–	–	48.4	–	91.2	–	68.8	–	75.0	71.4	2.3
ZAM	–	–	68.8	80.0	91.2	66.0	76.6	88.6	91.2	86.2	81.2	–	75.0	80.6	1.7
YUC	96.7	–	–	82.5	78.8	76.0	81.2	91.4	85.0	–	89.6	58.3	62.5	80.4	1.7
LAG	83.3	93.8	75.0	75.0	88.8	48.0	81.2	82.9	83.8	–	85.4	–	81.2	78.9	1.8
RAF	83.3	87.5	56.2	86.2	–	52.0	73.4	80.0	88.8	–	85.4	–	81.2	78.0	1.8
SIG	80.0	92.2	81.2	76.6	–	66.0	70.8	80.0	93.8	–	81.2	64.6	59.4	78.5	1.8
CHU	93.3	–	78.1	76.6	–	74.0	79.7	–	–	–	–	–	71.9	82.4	2.1
JOS	–	90.6	75.0	77.5	–	54.0	79.7	80.0	93.8	–	87.5	–	81.2	80.4	1.8
HUE	93.3	89.1	–	75.0	–	66.7	84.4	80.0	86.2	–	–	–	84.4	80.8	1.9
JIT	–	–	–	75.0	77.5	56.0	–	65.7	–	–	–	–	–	71.0	3.0
MPO	96.7	96.9	–	81.2	90.0	70.0	59.4	91.4	78.8	97.5	–	68.8	75.0	80.4	1.6
Corr. mean	88.2	91.4	72.2	79.4	85.8	62.8	72.3	80.9	87.2	91.7	83.5	66.5	73.6		
s.e.	1.7	1.0	2.2	1.1	1.4	1.7	1.5	1.7	1.0	1.3	1.4	2.9	1.8		
s.d.	5.4	3.3	6.0	4.7	3.8	5.9	5.4	6.4	3.7	3.0	5.2	6.9	7.7		
F.pr.	**	N.S.	**	N.S.	N.S.	N.S.	N.S.	N.S.	**	*	N.S.	N.S.	N.S.		

Table 24. Provenance–locality mean tree height (m) for 24 provenances of *Pinus oocarpa* / *P. patula* ssp. *tecunumanii* at 13 localities.

Prov	MEL	AGU	LDA	SPO	CCO	NBO	TUR	ANO	WIL	KBI	HBG	CPN	NDU	Corr. mean	s.e.
CAM	–	14.2	16.8	15.6	8.2	13.2	12.4	10.5	13.5	10.9	7.9	12.2	10.3	11.8	.15
SUL	7.5	–	–	–	–	–	–	–	–	–	–	–	–	11.1	.55
ZAP	7.0	13.1	16.1	13.3	7.2	12.1	10.8	8.2	12.4	–	6.5	–	8.7	10.5	.15
MAR	6.6	12.8	–	13.4	–	13.6	–	–	–	–	–	–	8.6	10.4	.20
CAN	–	–	16.0	–	7.2	–	–	–	11.8	9.6	6.8	11.8	9.1	10.5	.15
LIM	–	13.6	–	14.4	–	12.6	–	–	–	–	–	–	–	11.2	.25
CON	7.7	–	15.7	14.2	–	11.8	10.6	9.3	–	–	7.0	–	9.4	10.8	.20
MQT	–	–	–	–	–	–	–	–	–	8.8	–	9.5	9.3	9.8	.30
AGF	–	–	–	13.0	–	–	–	8.5	12.2	–	–	–	–	10.4	.25
PUE	–	13.0	15.9	–	–	–	–	–	–	–	–	–	–	10.5	.30
JUN	7.6	–	16.1	–	–	13.1	–	9.3	12.2	–	6.7	–	8.4	10.7	.20
BON	7.5	–	17.0	–	–	12.6	10.8	–	–	–	6.7	–	9.0	10.8	.25
BUC	5.8	13.1	15.8	13.9	–	12.5	9.8	8.3	–	8.8	7.0	–	9.0	10.3	.15
ANG	–	13.0	17.0	13.0	–	–	10.2	–	12.2	–	6.7	–	8.8	10.5	.15
ZAM	–	–	16.3	13.0	7.3	12.5	10.7	9.7	12.6	9.4	6.4	–	9.2	10.6	.15
YUC	7.2	–	–	14.8	9.1	14.9	12.7	10.9	13.8	–	7.6	12.3	10.5	12.0	.15
LAG	6.1	13.0	14.2	11.6	7.5	11.5	11.1	8.9	12.4	–	6.4	–	8.4	10.3	.15
RAF	7.9	14.1	16.9	14.5	–	14.1	11.3	10.6	13.1	–	7.6	–	10.1	11.5	.15
SIG	6.1	12.7	15.3	11.6	–	12.6	11.1	8.5	11.9	–	5.7	11.1	8.4	10.1	.15
CHU	6.4	–	15.1	12.7	–	11.7	10.0	–	–	–	–	–	9.3	10.0	.25
JOS	–	11.8	15.5	12.8	–	12.6	10.3	9.1	11.1	–	6.8	–	9.4	9.9	.15
HUE	5.8	12.2	–	12.1	–	12.0	10.2	7.8	10.6	–	–	–	7.4	9.4	.15
JIT	–	–	–	12.6	7.3	12.1	–	8.2	–	–	–	–	–	10.1	.25
MPO	8.9	13.6	–	14.9	8.4	13.7	11.3	11.4	12.3	10.2	–	13.1	9.0	11.4	.15
Corr. mean	7.0	13.1	16.0	13.4	7.5	12.7	10.8	9.2	12.2	9.5	6.7	11.3	9.1		
s.e.	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.2	0.1	0.1	0.1	0.2	0.2		
s.d.	0.4	0.3	0.6	0.4	0.3	0.4	0.4	0.4	0.3	0.3	0.4	0.5	0.6		
F.pr.	***	***	N.S.	***	**	***	***	***	***	***	*	*	N.S.		

Table 25. Provenance–locality mean tree diameter (cm) for 24 provenances of *Pinus oocarpa* / *P. patula* ssp. *tecunumanii* at 13 localities.

Prov	MEL	AGU	LDA	SPO	CCO	NBO	TUR	ANO	WIL	KBI	HBG	CPN	NDU	Corr. mean	s.e.
CAM	–	20.2	16.2	18.6	11.1	18.3	17.2	13.9	18.0	15.7	10.7	16.2	16.6	15.8	0.3
SUL	10.3	–	–	–	–	–	–	–	–	–	–	–	–	15.5	1.2
ZAP	9.1	18.0	15.0	15.4	10.2	13.8	14.2	9.7	16.4	–	9.0	–	12.5	13.8	0.3
MAR	8.2	17.4	–	16.5	–	17.2	–	–	–	–	–	–	13.2	14.1	0.5
CAN	–	–	17.3	–	10.1	–	–	–	17.0	14.4	9.5	15.5	13.8	14.5	0.3
LIM	–	19.1	–	18.1	–	15.8	–	–	–	–	–	–	–	15.8	0.6
CON	10.6	–	15.8	17.3	–	15.5	15.4	12.2	–	–	9.9	–	14.8	14.8	0.4
MQT	–	–	–	–	–	–	–	–	–	11.8	–	12.9	13.5	12.1	0.6
AGF	–	–	–	16.4	–	–	–	11.2	17.5	–	–	–	–	14.8	0.5
PUE	–	18.6	17.4	–	–	–	–	–	–	–	–	–	–	15.6	0.7
JUN	9.8	–	14.0	–	–	15.4	–	11.1	16.6	–	9.1	–	12.4	13.9	0.4
BON	10.0	–	17.1	–	–	17.0	15.4	–	–	–	9.4	–	13.6	14.7	0.5
BUC	7.0	18.4	16.3	18.0	–	16.3	13.6	11.0	–	12.8	9.3	–	14.3	14.1	0.4
ANG	–	16.8	17.3	17.2	–	–	14.2	–	16.2	–	9.2	–	12.5	14.1	0.3
ZAM	–	–	16.6	15.6	10.3	14.8	14.8	12.9	16.4	13.0	8.9	–	14.2	14.0	0.3
YUC	8.8	–	–	18.3	12.2	22.0	17.8	14.7	17.1	–	10.4	16.9	15.8	15.6	0.3
LAG	7.6	17.3	15.0	15.0	11.2	14.2	15.5	10.8	16.8	–	8.3	–	12.7	13.9	0.3
RAF	10.3	20.1	18.5	17.2	–	19.8	15.8	13.8	17.2	–	10.2	–	14.5	15.5	0.3
SIG	7.8	16.5	15.3	15.0	–	15.1	14.9	10.0	15.5	–	8.0	14.3	12.8	13.2	0.3
CHU	8.8	–	15.2	16.8	–	14.7	14.2	–	–	–	–	–	14.9	13.9	0.5
JOS	–	16.4	16.2	15.6	–	15.3	14.0	11.6	15.6	–	9.7	–	14.0	13.6	0.3
HUE	8.5	17.3	–	15.7	–	15.2	15.0	11.0	15.9	–	–	–	12.1	13.7	0.4
JIT	–	–	–	16.4	11.2	14.7	–	11.5	–	–	–	–	–	14.4	0.6
MPO	11.5	19.6	–	18.7	10.8	18.6	16.3	15.9	17.2	14.9	–	17.9	13.8	14.6	0.3
Corr. mean	9.2	17.5	16.3	16.8	10.7	16.3	15.3	12.1	16.7	14.0	9.4	15.7	14.0		
s.e.	0.3	0.2	0.3	0.2	0.3	0.6	0.3	0.6	0.2	0.4	0.2	0.4	0.4		
s.d.	0.6	0.5	0.6	0.6	0.5	0.8	0.6	0.8	0.4	0.5	0.5	0.5	1.1		
F.pr.	***	***	*	***	N.S.	***	***	***	***	***	*	**	N.S.		

Table 26. Provenance–locality mean tree volume under bark (dm³) for 24 provenances of *Pinus oocarpa* / *P. patula* ssp. *tecunumanii* at 13 localities.

Prov	MEL	AGU	LDA	SPO	CCO	NBO	TUR	ANO	WIL	KBI	HBG	CPN	NDU	Corr. mean	s.e.
CAM	–	266	224	252	30	189	140	91	185	98	26	147	98	161	6
SUL	19	–	–	–	–	–	–	–	–	–	–	–	–	151	62
ZAP	14	172	178	143	21	95	69	25	116	–	16	–	40	99	4
MAR	11	166	–	153	–	178	–	–	–	–	–	–	48	104	7
CAN	–	–	240	–	20	–	–	–	122	74	17	122	58	117	6
LIM	–	197	–	206	–	129	–	–	–	–	–	–	–	126	9
CON	22	–	181	181	–	102	81	51	–	–	16	–	65	110	8
MQT	–	–	–	–	–	–	–	–	–	43	–	56	53	69	6
AGF	–	–	–	158	–	–	–	37	129	–	–	–	–	111	8
PUE	–	181	240	–	–	–	–	–	–	–	–	–	–	117	8
JUN	20	–	162	–	–	134	–	45	123	–	15	–	37	102	6
BON	20	–	235	–	–	150	90	–	–	–	14	–	59	119	10
BUC	8	186	198	202	–	137	62	34	–	43	18	–	56	105	5
ANG	–	164	260	166	–	–	72	–	119	–	15	–	44	108	5
ZAM	–	–	213	137	16	114	81	57	124	55	12	–	52	102	5
YUC	15	–	–	206	49	334	172	109	176	–	25	155	100	171	9
LAG	8	167	169	110	23	98	92	39	137	–	10	–	42	100	4
RAF	25	239	284	206	–	252	105	89	161	–	23	–	74	148	8
SIG	9	137	174	112	–	123	90	29	104	–	8	100	40	88	3
CHU	11	–	181	158	–	106	63	–	–	–	–	–	65	98	7
JOS	–	123	189	129	–	123	63	46	87	–	17	–	65	87	4
HUE	10	156	–	132	–	122	75	31	102	–	–	–	31	92	4
JIT	–	–	–	151	29	120	–	38	–	–	–	–	–	109	11
MPO	36	245	–	255	33	228	117	125	155	84	–	183	64	156	6
Corr. mean	14	180	211	164	24	141	87	49	126	62	16	110	56		
s.e.	1	3	6	5	1	11	3	4	2	4	1	7	3		
s.d.	1	22	10	10	4	2	8	1	21	7	3	9	4		
F.pr.	**	***	N.S.	***	**	***	***	***	***	***	*	**	N.S.		

Table 27. Provenance–locality mean tree bark thickness (mm) for 24 provenances of *Pinus oocarpa* / *P. patula* ssp. *tecunumanii* at 13 localities.

Prov	MEL	AGU	LDA	SPO	CCO	NBO	TUR	ANO	WIL	KBI	HBG	CPN	NDU	Corr. mean	s.e.
CAM	–	15.5	13.1	17.6	15.2	17.5	19.4	13.2	17.9	15.9	13.0	16.2	19.3	15.5	0.5
SUL	15.7	–	–	–	–	–	–	–	–	–	–	–	–	18.8	1.3
ZAP	12.7	18.0	11.7	14.6	16.7	12.9	19.2	10.2	21.5	–	11.4	–	18.9	15.5	0.6
MAR	11.0	17.1	–	16.7	–	15.4	–	–	–	–	–	–	19.1	15.4	0.9
CAN	–	–	13.3	–	16.4	–	–	–	21.8	16.2	12.5	16.8	16.5	16.1	0.6
LIM	–	19.1	–	17.9	–	15.9	–	–	–	–	–	–	–	17.4	1.3
CON	15.5	–	13.0	17.4	–	16.5	21.6	13.9	–	–	14.4	–	20.1	17.5	0.7
MQT	–	–	–	–	–	–	–	–	–	15.3	–	14.3	18.5	14.6	0.9
AGF	–	–	–	16.9	–	–	–	12.2	25.1	–	–	–	–	18.6	1.1
PUE	–	20.2	14.9	–	–	–	–	–	–	–	–	–	–	18.5	1.1
JUN	13.0	–	10.8	–	–	15.2	–	10.9	20.6	–	12.1	–	16.9	15.6	0.7
BON	13.0	–	13.8	–	–	15.6	19.8	–	–	–	12.5	–	17.2	16.1	0.8
BUC	8.3	18.0	14.1	18.1	–	15.8	18.3	12.7	–	17.3	12.0	–	19.8	16.0	0.6
ANG	–	14.5	11.9	16.5	–	–	17.3	–	20.7	–	11.2	–	16.2	15.2	0.7
ZAM	–	–	12.5	15.1	20.0	14.3	19.8	13.4	22.1	15.1	12.3	–	19.9	16.1	0.6
YUC	11.6	–	–	16.3	14.2	17.1	15.6	11.4	15.8	–	11.1	15.3	13.7	13.9	0.6
LAG	10.2	15.3	10.5	13.6	18.9	11.7	18.7	10.8	19.6	–	12.8	–	15.0	14.6	0.6
RAF	11.9	16.7	14.4	15.3	–	16.9	16.0	11.0	16.8	–	11.3	–	14.6	14.6	0.6
SIG	10.7	16.3	11.4	13.5	–	13.8	18.3	10.7	19.4	–	12.7	14.6	17.3	14.6	0.5
CHU	13.6	–	12.5	17.5	–	15.2	20.3	–	–	–	–	–	19.6	16.4	0.8
JOS	–	17.3	13.2	15.7	–	15.5	20.3	11.9	22.7	–	12.3	–	17.4	16.5	0.6
HUE	12.3	13.7	–	14.0	–	12.1	18.9	10.7	17.4	–	–	–	15.1	13.7	0.7
JIT	–	–	–	15.6	17.4	13.6	–	12.4	–	–	–	–	–	15.4	1.2
MPO	13.8	13.6	–	16.2	13.0	14.2	16.0	12.1	15.5	13.8	–	15.0	13.7	13.6	0.5
Corr. mean	12.7	16.9	12.6	16.3	17.2	15.3	19.1	12.2	20.3	16.1	12.5	16.3	17.8		
s.e.	0.4	0.5	0.4	0.5	0.7	0.8	0.7	0.6	0.4	0.5	0.5	0.6	0.6		
s.d.	0.6	0.7	0.7	0.7	0.7	0.9	1.0	0.8	0.5	0.5	0.8	0.5	1.5		
F.pr.	***	***	*	**	***	***	**	*	***	***	N.S.	*	N.S.		

Table 28. Provenance–locality mean tree bark proportion (% of total tree volume overbark) for 24 provenances of *Pinus oocarpa* / *P. patula* ssp. *tecunumanii* at 13 localities.

Prov	MEL	AGU	LDA	SPO	CCO	NBO	TUR	ANO	WIL	KBI	HBG	CPN	NDU	Corr. mean	s.e.
CAM	–	25.0	25.6	28.9	45.1	28.7	35.2	32.3	30.8	33.1	41.9	31.6	36.9	31.2	0.7
SUL	51.3	–	–	–	–	–	–	–	–	–	–	–	–	39.3	3.0
ZAP	47.9	32.0	24.5	30.2	54.0	29.5	42.8	38.2	40.4	–	45.1	–	49.6	36.6	0.5
MAR	46.5	31.9	–	31.7	–	28.4	–	–	–	–	–	–	47.9	36.6	1.0
CAN	–	–	24.0	–	52.3	–	–	–	40.1	37.8	45.0	34.5	39.4	35.6	0.9
LIM	–	31.5	–	30.8	–	31.7	–	–	–	–	–	–	–	36.1	1.0
CON	49.4	–	26.2	31.9	–	33.4	44.0	39.0	–	–	49.9	–	45.3	37.4	1.0
MQT	–	–	–	–	–	–	–	–	–	43.0	–	36.6	44.7	38.3	1.4
AGF	–	–	–	32.0	–	–	–	37.5	43.4	–	–	–	–	38.4	1.1
PUE	–	34.7	26.5	–	–	–	–	–	–	–	–	–	–	39.6	1.3
JUN	45.4	–	24.9	–	–	29.8	–	34.4	38.4	–	46.2	–	45.4	35.5	1.1
BON	45.2	–	24.7	–	–	28.7	39.8	–	–	–	46.2	–	42.2	34.9	1.4
BUC	42.1	31.8	27.4	30.8	–	29.6	43.4	40.4	–	44.4	45.8	–	44.8	36.7	0.8
ANG	–	28.1	21.7	30.5	–	–	39.7	–	39.5	–	43.1	–	42.8	34.6	0.8
ZAM	–	–	22.6	30.8	61.2	30.2	42.1	35.5	41.1	37.8	47.8	–	45.5	37.0	0.8
YUC	45.6	–	–	27.5	37.4	24.4	27.3	26.5	29.3	–	37.5	29.5	29.5	28.5	0.8
LAG	47.0	28.8	22.5	30.1	53.3	26.9	38.4	34.6	35.9	–	53.2	–	40.3	34.4	0.7
RAF	40.6	27.0	23.6	27.2	–	25.6	34.3	27.4	30.9	–	39.1	–	33.5	30.7	0.7
SIG	47.9	31.8	23.4	29.6	–	28.9	38.9	37.6	39.1	–	54.7	32.4	45.7	35.6	0.7
CHU	52.9	–	25.0	32.9	–	33.2	44.5	–	–	–	–	–	42.6	37.8	1.0
JOS	–	33.8	25.5	31.6	–	30.4	44.8	35.5	45.1	–	44.2	–	41.0	38.2	0.7
HUE	50.2	25.9	–	28.2	–	25.6	40.8	34.8	35.6	–	–	–	43.6	33.0	0.8
JIT	–	–	–	29.4	51.8	28.9	–	40.0	–	–	–	–	–	34.7	1.2
MPO	40.8	22.6	–	26.6	39.6	23.8	32.6	25.5	29.4	31.5	–	26.8	34.2	28.0	0.7
Corr. mean	47.3	30.3	24.2	30.6	51.4	29.5	40.3	35.6	38.3	38.8	46.3	34.4	42.4		
s.e.	0.6	0.4	0.6	0.3	0.9	1.0	0.9	1.7	0.4	1.0	1.2	0.8	0.9		
s.d.	1.5	1.0	1.5	0.9	1.6	1.6	2.3	2.6	1.0	1.5	2.8	1.2	2.5		
F.pr.	***	***	N.S.	**	***	***	***	***	***	***	N.S.	*	**		

Table 29. Provenance–locality mean stem form (index) for 24 provenances of *Pinus oocarpa* / *P. patula* ssp. *tecunumanii* at 12 localities.

Prov	MEL	AGU	LDA	SPO	CCO	NBO	TUR	ANO	WIL	KBI	HBG	CPN	NDU	Corr. mean	s.e.
CAM	–	38.2	29.1	37.4	31.8	30.5	36.6	37.7	31.0	34.8	49.0	40.3	31.6	35.7	0.8
SUL	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
ZAP	–	37.3	27.8	35.7	28.8	31.7	37.4	30.3	28.0	–	48.9	–	30.0	34.4	0.9
MAR	–	34.5	–	38.2	–	35.3	–	–	–	–	–	–	29.8	35.9	1.4
CAN	–	–	29.6	–	27.9	–	–	–	26.0	32.9	47.1	45.1	28.9	33.5	1.0
LIM	–	35.6	–	35.5	–	31.1	–	–	–	–	–	–	–	34.5	1.6
CON	–	–	23.4	31.1	–	25.5	27.1	31.2	–	–	41.5	–	25.2	29.3	1.0
MQT	–	–	–	–	–	–	–	–	–	30.9	–	47.6	29.2	34.6	1.6
AGF	–	–	–	35.0	–	–	–	35.6	26.1	–	–	–	–	34.1	1.6
PUE	–	28.5	27.1	–	–	–	–	–	–	–	–	–	–	27.7	2.0
JUN	–	–	32.9	–	–	32.3	–	36.7	27.6	–	46.9	–	29.0	35.0	1.1
BON	–	–	27.7	–	–	31.4	31.9	–	–	–	56.0	–	27.2	34.9	1.2
BUC	–	30.8	23.1	33.6	–	31.3	27.6	29.1	–	28.6	43.6	–	24.2	30.3	0.9
ANG	–	34.6	26.1	37.6	–	–	32.6	–	27.7	–	57.3	–	29.5	35.4	1.0
ZAM	–	–	23.2	33.0	29.2	28.7	29.6	39.0	27.6	30.4	47.3	–	30.2	33.0	0.9
YUC	–	–	–	33.7	33.2	34.1	35.3	37.2	31.6	–	47.0	44.8	36.1	36.2	0.9
LAG	–	42.7	29.3	35.0	31.3	29.8	35.4	38.2	33.1	–	52.0	–	32.1	36.7	0.9
RAF	–	45.0	27.2	36.9	–	34.7	36.2	37.8	32.4	–	50.1	–	37.7	38.1	0.9
SIG	–	35.8	26.8	31.3	–	31.9	31.4	32.5	27.1	–	37.8	47.2	26.7	32.3	0.9
CHU	–	–	27.7	30.8	–	26.3	27.3	–	–	–	–	–	24.9	30.4	1.2
JOS	–	31.0	27.9	30.4	–	31.5	28.1	32.3	25.8	–	52.4	–	28.0	32.5	0.9
HUE	–	25.1	–	22.9	–	26.0	24.4	23.8	21.8	–	–	–	22.7	25.7	1.0
JIT	–	–	–	25.7	27.4	27.7	–	24.5	–	–	–	–	–	27.8	1.4
MPO	–	31.1	–	28.5	30.2	28.8	30.1	31.1	25.4	28.4	–	41.1	26.8	31.0	0.9
Corr. mean	–	34.2	27.0	32.9	29.4	30.5	31.3	33.3	27.1	31.0	47.2	43.5	28.5		
s.e.	–	0.8	0.7	0.7	1.0	0.7	0.7	0.7	0.8	1.2	0.7	1.2	0.6		
s.d.	–	2.0	2.2	1.9	0.8	1.9	2.1	1.9	1.0	1.1	3.9	1.8	1.8		
F.pr.	–	***	N.S.	***	***	**	***	***	***	**	N.S.	N.S.	**		

Table 30. Provenance–locality mean percentage of trees with stem lean greater than 2.5° for 24 provenances of *Pinus oocarpa* / *P. patula* ssp. *tecunumanii* at 13 localities.

Prov	MEL	AGU	LDA	SPO	CCO	NBO	TUR	ANO	WIL	KBI	HBG	CPN	NDU	Corr. mean	s.e.
CAM	–	23.2	32.0	49.3	31.0	41.9	56.0	27.3	19.4	14.5	0	18.9	62.5	31.1	1.9
SUL	14.8	–	–	–	–	–	–	–	–	–	–	–	–	50.4	12.2
ZAP	3.8	9.8	35.0	27.7	40.6	25.0	28.0	16.7	–	–	0	–	45.8	23.7	1.8
MAR	3.8	18.2	–	12.3	–	28.6	–	–	–	–	–	–	20.8	17.6	2.6
CAN	–	–	41.7	–	34.3	–	–	–	17.2	10.8	0	2.5	42.3	22.8	2.5
LIM	–	12.3	–	29.5	–	26.7	–	–	–	–	–	–	–	22.1	3.2
CON	6.9	–	33.3	25.8	–	28.6	48.0	19.2	–	–	0	–	50.0	25.6	2.4
MQT	–	–	–	–	–	–	–	–	–	8.6	–	2.8	32.1	17.2	3.8
AGF	–	–	–	29.5	–	–	–	15.4	21.6	–	–	–	–	24.6	3.2
PUE	–	15.0	20.0	–	–	–	–	–	–	–	–	–	–	16.8	3.7
JUN	17.9	–	25.0	–	–	21.4	–	21.4	15.4	–	5.1	–	41.7	24.6	3.0
BON	0	–	28.6	–	–	36.7	21.6	–	–	–	0	–	52.0	24.4	3.2
BUC	0	19.0	41.7	20.3	–	32.1	52.7	14.2	–	16.7	0	–	38.5	25.8	2.1
ANG	–	8.8	50.0	11.7	–	–	31.1	–	15.1	–	2.3	–	33.3	18.6	2.1
ZAM	–	–	25.0	21.9	38.4	24.2	27.5	9.7	20.5	7.2	0	–	28.0	20.2	1.8
YUC	0	–	–	27.3	21.2	42.1	38.9	40.6	13.2	–	2.4	18.4	29.2	23.8	2.0
LAG	0	10.0	25.0	13.9	33.3	33.3	34.8	17.2	7.5	–	0	–	22.2	15.8	1.7
RAF	4.0	8.9	50.0	40.6	–	26.9	27.5	21.4	9.9	–	0	–	11.1	20.9	2.0
SIG	0	13.6	30.8	26.5	–	15.2	28.9	17.9	16.0	–	7.7	10.8	66.7	22.4	2.0
CHU	7.1	–	44.0	40.8	–	32.4	40.4	–	–	–	–	–	50.0	29.6	2.8
JOS	–	13.8	33.3	24.2	–	37.0	32.1	35.7	32.0	–	0	–	23.1	25.6	2.2
HUE	10.7	19.3	–	38.3	–	43.3	34.5	25.0	24.6	–	–	–	70.4	30.8	2.3
JIT	–	–	–	45.8	50.0	35.7	–	21.7	–	–	–	–	–	33.7	3.2
MPO	3.4	38.7	–	43.1	44.4	48.6	48.9	37.5	33.3	20.5	–	5.9	40.0	35.2	1.9
Corr. mean	4.6	17.1	37.3	29.2	35.3	32.2	35.9	22.2	19.7	12.5	1.3	9.0	41.3		
s.e.	1.1	1.4	2.6	1.4	2.2	2.0	1.8	2.0	1.3	1.6	5.0	1.8	2.3		
s.d.	3.2	4.6	9.1	5.8	5.6	8.2	6.6	7.4	5.4	3.8	1.0	5.2	9.4		
F.pr.	*	*	N.S.	*	*	N.S.	**	N.S.	N.S.	N.S.	***	N.S.	N.S.		

Table 31. Provenance–locality mean percentage of trees with forks or multiple stems for 24 provenances of *Pinus oocarpa* / *P. patula* ssp. *tecunumanii* at 13 localities.

Prov	MEL	AGU	LDA	SPO	CCO	NBO	TUR	ANO	WIL	KBI	HBG	CPN	NDU	Corr. mean	s.e.
CAM	–	17.9	32.0	22.4	8.5	22.6	8.0	15.0	34.4	20.9	8.9	21.2	12.5	20.3	1.6
SUL	0	–	–	–	–	–	–	–	–	–	–	–	–	0	0.6
ZAP	15.9	44.2	70.0	75.4	2.8	28.1	8.0	24.6	35.3	–	7.5	–	29.2	32.7	2.0
MAR	15.9	49.0	–	55.4	–	28.6	–	–	–	–	–	–	25.0	31.4	2.9
CAN	–	–	37.5	–	1.5	–	–	–	20.4	24.3	16.7	10.5	11.6	21.2	2.4
LIM	–	45.5	–	49.2	–	33.3	–	–	–	–	–	–	–	29.3	3.2
CON	0	–	50.0	40.9	–	34.3	10.0	0	–	–	9.8	–	16.7	21.4	2.3
MQT	–	–	–	–	–	–	–	–	–	16.9	–	21.1	14.3	21.5	3.8
AGF	–	–	–	44.3	–	–	–	15.1	10.8	–	–	–	–	18.9	2.7
PUE	–	46.8	55.0	–	–	–	–	–	–	–	–	–	–	28.2	3.8
JUN	10.4	–	58.3	–	–	39.3	–	28.3	33.7	–	22.9	–	25.0	33.2	3.0
BON	10.9	–	57.1	–	–	26.7	7.8	–	–	–	13.4	–	20.0	26.5	3.5
BUC	0	20.6	62.6	28.1	–	7.1	3.6	7.1	–	8.3	9.2	–	7.7	14.9	1.6
ANG	–	50.9	67.0	53.3	–	–	2.2	–	30.3	–	9.4	–	20.8	28.4	2.3
ZAM	–	–	67.0	57.8	4.1	30.3	13.7	38.2	16.5	20.3	23.1	–	16.0	28.0	2.1
YUC	3.4	–	–	18.2	6.1	21.1	12.9	3.1	17.7	–	2.3	9.0	8.3	16.0	1.8
LAG	15.5	59.9	62.6	66.7	4.1	45.8	22.5	42.0	27.0	–	13.6	–	33.3	35.5	2.2
RAF	7.7	16.0	12.5	15.9	–	19.2	7.9	3.6	25.4	–	12.3	–	11.1	14.5	1.6
SIG	17.1	49.1	73.0	46.9	–	42.4	13.4	43.0	26.5	–	12.8	30.0	12.5	31.4	2.1
CHU	3.7	–	48.0	36.7	–	8.1	9.6	–	–	–	–	–	7.7	17.9	2.5
JOS	–	53.4	37.5	41.9	–	14.8	7.6	28.8	24.0	–	11.8	–	45.9	25.1	2.1
HUE	10.9	42.0	–	55.0	–	16.7	16.4	31.7	39.0	–	–	–	33.3	31.9	2.3
JIT	–	–	–	37.5	0	14.3	–	12.8	–	–	–	–	–	16.2	2.9
MPO	3.5	29.0	–	13.8	11.0	25.7	2.1	18.9	25.2	19.2	–	10.2	16.0	19.1	1.7
Corr. mean	12.2	36.1	51.2	42.2	7.8	25.2	10.0	22.0	24.8	21.8	12.0	18.3	18.4		
s.e.	1.7	1.8	2.6	1.5	1.2	1.8	1.1	2.0	1.4	2.3	1.3	2.8	1.8		
s.d.	4.4	6.1	9.8	6.1	2.2	7.4	4.0	6.7	5.1	4.4	4.9	6.0	7.7		
F.pr.	*	***	*	***	N.S.	*	N.S.	***	*	N.S.	N.S.	N.S.	N.S.		

Table 32. Provenance–locality mean tree values of the mean number of branches per whorl for 24 provenances of *Pinus oocarpa* / *P. patula* ssp. *tecunumanii* at 13 localities.

Prov	MEL	AGU	LDA	SPO	CCO	NBO	TUR	ANO	WIL	KBI	HBG	CPN	NDU	Corr. mean	s.e.
CAM	–	4.46	4.36	4.53	3.93	4.46	4.66	3.34	4.37	4.47	4.01	3.95	4.33	4.20	.06
SUL	3.56	–	–	–	–	–	–	–	–	–	–	–	–	4.01	.20
ZAP	3.40	3.77	4.00	3.52	3.40	3.94	3.80	2.66	3.80	–	3.60	–	3.54	3.59	.06
MAR	3.08	3.84	–	3.43	–	4.09	–	–	–	–	–	–	3.38	3.54	.09
CAN	–	–	4.50	–	3.32	–	–	–	3.85	3.97	3.74	3.85	3.88	3.82	.07
LIM	–	3.95	–	3.84	–	3.92	–	–	–	–	–	–	–	3.72	.11
CON	3.43	–	4.00	3.75	–	4.14	3.86	3.19	–	–	3.73	–	3.62	3.74	.07
MQT	–	–	–	–	–	–	–	–	–	4.02	–	3.49	3.62	3.67	.12
AGF	–	–	–	3.67	–	–	–	2.92	3.75	–	–	–	–	3.59	.11
PUE	–	3.95	4.44	–	–	–	–	–	–	–	–	–	–	3.88	.14
JUN	3.43	–	4.00	–	–	4.18	–	3.40	4.03	–	3.69	–	3.50	3.78	.07
BON	3.54	–	4.43	–	–	4.27	4.01	–	–	–	3.54	–	3.76	3.86	.08
BUC	3.21	3.86	4.38	3.88	–	3.96	3.44	2.72	–	3.62	3.60	–	3.70	3.63	.06
ANG	–	3.81	4.16	3.40	–	–	3.82	–	3.92	–	3.69	–	3.67	3.65	.07
ZAM	–	–	3.92	3.53	3.35	3.76	3.88	3.24	3.91	3.82	3.74	–	3.72	3.66	.06
YUC	3.30	–	–	4.41	4.27	5.01	4.94	3.87	4.41	–	4.44	4.28	4.67	4.44	.06
LAG	2.89	3.91	3.84	3.47	3.53	3.88	3.89	3.16	4.12	–	3.37	–	3.60	3.61	.06
RAF	3.66	4.52	4.34	4.38	–	4.32	4.25	3.40	4.44	–	3.92	–	4.43	4.15	.06
SIG	3.24	3.70	4.04	3.38	–	3.81	3.82	2.94	3.69	–	3.20	3.66	3.68	3.55	.06
CHU	3.18	–	4.12	3.66	–	3.78	3.69	–	–	–	–	–	3.73	3.61	.08
JOS	–	3.67	4.00	3.48	–	3.84	3.54	3.02	3.66	–	3.92	–	3.74	3.58	.06
HUE	3.25	3.64	–	3.45	–	4.06	3.49	2.49	3.59	–	–	–	3.41	3.44	.07
JIT	–	–	–	3.69	3.43	3.75	–	2.80	–	–	–	–	–	3.56	.10
MPO	3.59	4.34	–	4.47	3.60	4.32	4.21	3.81	4.03	3.88	–	4.38	3.84	4.07	.06
Corr. mean	3.32	3.98	4.18	3.80	3.50	4.08	3.93	3.12	3.94	3.88	3.69	3.74	3.78		
s.e.	.05	.06	.05	.05	.07	.05	.05	.05	.05	.08	.05	.08	.05		
s.d.	.14	.08	.16	.15	.09	.15	.18	.15	.09	.13	.14	.06	.26		
F.pr.	*	***	N.S.	***	***	***	***	***	***	**	***	***	***		

Table 33. Provenance–locality mean tree value of number of whorls (between 1 m and 6 m above ground) for 24 provenances of *Pinus oocarpa* / *P. patula* ssp. *tecunumanii* at 13 localities.

Prov	MEL	AGU	LDA	SPO	CCO	NBO	TUR	ANO	WIL	KBI	HBG	CPN	NDU	Corr. mean	s.e.
CAM	–	10.1	11.2	12.3	9.7	12.3	10.7	11.9	9.0	11.5	11.2	10.2	10.8	11.2	.15
SUL	16.4	–	–	–	–	–	–	–	–	–	–	–	–	12.4	.54
ZAP	16.6	11.5	11.6	12.0	9.7	12.4	11.5	12.4	11.4	–	9.8	–	11.5	11.8	.16
MAR	15.7	11.0	–	12.1	–	12.4	–	–	–	–	–	–	11.4	11.6	.24
CAN	–	–	10.9	–	10.4	–	–	–	10.5	11.7	11.4	9.8	12.4	11.8	.20
LIM	–	10.7	–	11.8	–	12.9	–	–	–	–	–	–	–	11.6	.31
CON	15.1	–	10.4	12.7	–	12.5	11.4	13.4	–	–	11.6	–	12.0	11.8	.19
MQT	–	–	–	–	–	–	–	–	–	12.0	–	10.8	12.1	11.9	.32
AGF	–	–	–	11.4	–	–	–	11.4	10.2	–	–	–	–	10.8	.31
PUE	–	11.2	11.0	–	–	–	–	–	–	–	–	–	–	11.8	.38
JUN	15.6	–	11.7	–	–	12.5	–	12.6	10.6	–	9.8	–	10.6	11.4	.20
BON	16.0	–	12.1	–	–	12.2	11.1	–	–	–	10.8	–	11.9	11.8	.22
BUC	17.4	11.3	10.8	11.9	–	12.9	11.8	13.4	–	11.8	11.2	–	12.1	12.1	.17
ANG	–	10.5	10.6	12.4	–	–	11.2	–	10.4	–	11.0	–	12.0	11.6	.20
ZAM	–	–	10.7	11.2	10.0	11.7	10.9	12.6	10.5	11.5	11.1	–	11.7	11.4	.17
YUC	14.9	–	–	12.1	9.5	12.3	11.2	12.6	9.5	–	12.2	11.2	11.8	11.6	.17
LAG	15.8	11.2	11.2	13.0	10.2	12.1	11.7	12.7	11.3	–	10.9	–	12.1	11.9	.16
RAF	14.6	9.6	10.9	12.9	–	11.8	11.7	12.2	9.8	–	10.9	–	11.2	11.3	.17
SIG	15.9	10.8	11.0	12.0	–	11.9	10.5	12.5	10.4	–	10.0	9.8	11.6	11.3	.16
CHU	16.9	–	11.4	12.8	–	12.5	11.6	–	–	–	–	–	12.8	12.2	.22
JOS	–	11.8	11.6	12.5	–	12.4	11.3	12.5	11.2	–	11.2	–	13.1	12.1	.18
HUE	17.0	12.6	–	14.0	–	13.9	12.2	13.7	12.0	–	–	–	13.1	13.1	.19
JIT	–	–	–	14.5	10.4	13.9	–	14.1	–	–	–	–	–	13.1	.27
MPO	13.2	8.5	–	11.2	8.8	11.3	10.5	10.4	8.1	9.9	–	9.6	10.0	10.0	.16
Corr. mean	15.8	10.9	11.2	12.4	10.0	12.4	11.3	12.6	10.6	11.7	11.0	10.7	11.8		
s.e.	.15	.15	.14	.13	.20	.13	.14	.14	.15	.23	.15	.23	.13		
s.d.	.51	.25	.45	.41	.25	.31	.39	.45	.27	.23	.51	.23	.59		
F.pr.	***	***	N.S.	***	**	***	N.S.	***	***	***	N.S.	**	N.S.		

Table 34. Provenance–locality mean tree value of longest internode length (m) for 24 provenances of *Pinus oocarpa* / *P. patula* ssp. *tecunumanii* at 13 localities.

Prov	MEL	AGU	LDA	SPO	CCO	NBO	TUR	ANO	WIL	KBI	HBG	CPN	NDU	Corr. mean	s.e.
CAM	–	8.1	6.0	6.8	7.7	5.3	7.0	8.7	7.8	6.9	6.9	8.0	6.9	7.0	.23
SUL	4.6	–	–	–	–	–	–	–	–	–	–	–	–	6.3	.82
ZAP	5.3	6.7	6.7	6.6	6.9	5.6	6.3	7.4	6.5	–	6.4	–	6.6	6.6	.24
MAR	5.2	7.1	–	6.8	–	6.7	–	–	–	–	–	–	6.5	6.7	.36
CAN	–	–	7.2	–	6.1	–	–	–	6.8	7.2	6.6	8.5	6.2	6.8	.31
LIM	–	7.8	–	7.0	–	6.2	–	–	–	–	–	–	–	6.8	.47
CON	6.0	–	7.6	6.9	–	6.2	6.5	6.8	–	–	5.6	–	6.4	6.8	.29
MQT	–	–	–	–	–	–	–	–	–	6.4	–	6.2	6.0	5.9	.48
AGF	–	–	–	6.9	–	–	–	8.0	7.3	–	–	–	–	7.2	.47
PUE	–	7.8	7.5	–	–	–	–	–	–	–	–	–	–	7.1	.58
JUN	5.2	–	5.7	–	–	7.4	–	6.0	6.7	–	6.5	–	6.7	6.6	.31
BON	4.7	–	6.6	–	–	6.2	8.2	–	–	–	6.2	–	5.9	6.7	.33
BUC	4.0	6.6	6.4	6.8	–	5.8	6.0	6.0	–	6.9	6.3	–	6.3	6.2	.25
ANG	–	8.0	6.9	7.1	–	–	7.0	–	6.9	–	6.4	–	6.2	6.8	.31
ZAM	–	–	7.7	7.3	6.7	8.5	6.7	6.1	6.6	7.2	6.4	–	6.6	7.0	.25
YUC	6.3	–	–	6.7	7.3	7.0	8.1	6.1	10.1	–	7.1	7.9	7.1	7.5	.25
LAG	4.7	6.9	6.8	7.0	6.2	7.3	6.4	6.0	6.6	–	6.6	–	6.0	6.5	.24
RAF	5.4	9.7	7.8	6.8	–	10.1	6.6	7.4	9.1	–	7.8	–	7.5	7.9	.26
SIG	4.8	7.1	7.4	6.8	–	6.1	7.3	7.3	7.1	–	5.4	8.1	5.7	6.7	.24
CHU	5.0	–	6.8	6.4	–	6.2	6.8	–	–	–	–	–	5.9	6.5	.33
JOS	–	6.8	6.8	6.9	–	6.6	6.1	7.7	6.0	–	5.9	–	5.8	6.4	.27
HUE	4.4	6.4	–	6.0	–	5.7	6.1	5.5	6.8	–	–	–	6.1	6.0	.29
JIT	–	–	–	6.4	6.4	5.0	–	5.1	–	–	–	–	–	5.8	.41
MPO	7.8	13.5	–	8.9	9.7	8.9	10.6	11.2	14.7	10.8	–	10.5	12.4	10.8	.24
Corr. mean	5.1	7.7	7.0	6.8	6.7	6.7	6.9	6.9	7.5	7.2	6.5	7.6	6.6		
s.e.	.22	.23	.22	.20	.30	.20	.22	.22	.22	.35	.22	.35	.19		
s.d.	.60	.92	.63	.43	.53	.63	.83	1.10	.59	.57	.48	.53	.26		
F.pr.	*	***	N.S.	*	**	***	*	*	***	***	N.S.	**	***		

Table 35. Provenance–locality value of the percentage of trees with fine or medium/fine branches for 24 provenances of *Pinus oocarpa* / *P. patula* ssp. *tecunumanii* at 13 localities.

Prov	MEL	AGU	LDA	SPO	CCO	NBO	TUR	ANO	WIL	KBI	HBG	CPN	NDU	Corr. mean	s.e.
CAM	–	44.6	44.0	45.3	67.6	25.8	62.0	48.5	49.3	35.5	51.1	27.0	25.0	46.8	2.1
SUL	33.3	–	–	–	–	–	–	–	–	–	–	–	–	44.0	10.1
ZAP	57.7	54.1	67.5	57.6	71.0	59.4	66.0	66.7	53.5	–	62.5	–	58.3	57.8	2.2
MAR	38.5	47.3	–	36.1	–	48.6	–	–	–	–	–	–	50.0	53.1	3.5
CAN	–	–	54.2	–	68.7	–	–	–	45.3	25.7	54.8	37.5	38.5	47.1	2.9
LIM	–	63.2	–	60.9	–	53.3	–	–	–	–	–	–	–	52.7	4.1
CON	24.1	–	62.5	22.4	–	42.9	44.0	50.0	–	–	48.8	–	29.2	44.4	2.8
MQT	–	–	–	–	–	–	–	–	–	60.0	–	47.2	67.9	70.7	3.8
AGF	–	–	–	42.6	–	–	–	50.0	39.2	–	–	–	–	42.0	3.9
PUE	–	50.0	57.5	–	–	–	–	–	–	–	–	–	–	47.2	5.0
JUN	50.0	–	67.0	–	–	50.0	–	71.4	55.4	–	59.0	–	62.5	59.4	3.2
BON	32.1	–	57.1	–	–	26.7	58.8	–	–	–	40.0	–	48.0	43.8	3.6
BUC	23.8	61.9	54.2	43.8	–	28.6	49.1	46.4	–	29.2	70.0	–	23.1	45.3	2.4
ANG	–	42.1	20.8	31.7	–	–	48.9	–	42.5	–	62.8	–	54.2	40.8	2.7
ZAM	–	–	41.7	45.3	82.2	54.5	56.9	58.1	54.8	44.9	46.2	–	48.0	53.4	2.4
YUC	51.7	–	–	57.6	71.2	26.3	44.4	50.0	50.0	–	53.5	44.7	29.2	48.8	2.4
LAG	40.0	56.7	41.7	36.1	50.0	33.3	56.6	51.7	46.3	–	54.5	–	51.9	44.0	2.3
RAF	20.0	58.9	33.3	60.9	–	26.9	58.8	42.9	46.5	–	34.1	–	37.0	45.0	2.4
SIG	41.7	55.9	50.0	22.4	–	39.4	81.6	75.0	40.0	–	48.7	29.7	33.3	46.7	2.4
CHU	35.7	–	56.0	34.7	–	56.8	48.1	–	–	–	–	–	26.9	44.1	3.4
JOS	–	44.8	45.8	38.7	–	29.6	56.6	57.1	53.3	–	42.9	–	38.5	44.1	2.5
HUE	28.6	52.6	–	33.3	–	46.7	50.9	42.9	24.6	–	–	–	29.6	38.0	2.6
JIT	–	–	–	18.8	61.8	42.9	–	39.1	–	–	–	–	–	35.0	3.7
MPO	24.1	58.1	–	50.8	65.3	11.4	51.1	40.6	30.2	21.8	–	12.0	40.0	38.8	2.1
Corr. mean	36.2	53.9	50.4	46.9	67.6	39.3	56.5	53.4	45.4	32.5	51.4	29.8	40.4		
s.e.	2.6	1.9	2.7	1.6	2.1	2.1	1.8	2.4	1.6	2.4	2.1	3.1	2.3		
s.d.	9.0	6.4	10.5	6.2	5.5	8.3	6.9	9.2	5.8	5.4	7.5	7.5	9.7		
F.pr.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	***	**	*	N.S.	*		

Table 36. Provenance–locality mean percentage of trees with cones for 24 provenances of *Pinus oocarpa* / *P. patula* ssp. *tecunumanii* at 13 localities.

Prov	MEL	AGU	LDA	SPO	CCO	NBO	TUR	ANO	WIL	KBI	HBG	CPN	NDU	Corr. mean	s.e.	
CAM	–	39.3	4.0	1.5	–	51.6	0.0	0.0	28.4	53.9	2.2	3.1	4.2	15.0	1.3	
SUL	33.3	–	–	–	–	–	–	–	–	–	–	–	–	39.0	7.6	
ZAP	7.7	36.1	10.0	1.5	–	15.6	0.0	0.0	21.1	–	5.0	–	4.2	10.9	1.3	
MAR	7.7	38.2	–	0.0	–	34.3	–	–	–	–	–	–	16.7	13.3	1.9	
CAN	–	–	16.7	–	–	–	–	–	21.9	48.6	7.1	15.9	15.4	17.1	1.9	
LIM	–	49.1	–	19.7	–	66.8	–	–	–	–	–	–	–	27.5	2.9	
CON	31.0	–	8.2	39.4	–	77.1	8.0	30.8	–	–	24.4	–	12.5	38.2	2.5	
MQT	–	–	–	–	–	–	–	–	–	28.6	–	0.0	14.3	9.3	2.0	
AGF	–	–	–	0.0	–	–	–	3.8	39.4	–	–	–	–	8.7	2.0	
PUE	–	48.3	22.5	–	–	–	–	–	–	–	–	–	–	23.8	3.2	
JUN	17.9	–	0.0	–	–	42.9	–	3.6	23.2	–	0.0	–	8.3	19.0	2.2	
BON	32.1	–	21.4	–	–	70.0	3.9	–	–	–	6.7	–	20.0	29.5	3.2	
BUC	9.5	63.5	16.7	43.4	–	82.1	9.1	25.0	–	51.4	14.0	–	3.8	28.7	1.9	
ANG	–	35.1	12.5	20.0	–	–	0.0	–	27.4	–	2.3	–	0.0	16.0	1.8	
ZAM	–	–	16.7	3.1	–	36.4	2.0	0.0	15.1	34.8	5.1	–	4.0	10.2	1.3	
YUC	3.4	–	–	0.0	–	71.1	0.0	3.1	30.9	–	0.0	5.6	12.5	15.9	1.8	
LAG	8.0	23.3	0.0	0.0	–	12.5	3.8	3.4	46.3	–	0.0	–	7.4	12.9	1.5	
RAF	4.0	41.1	0.0	0.0	–	30.8	3.9	0.0	36.6	–	4.9	–	0.0	13.9	1.5	
SIG	8.3	33.9	3.8	4.1	–	36.4	2.6	7.1	28.0	–	5.1	6.3	16.7	14.4	1.5	
CHU	35.7	–	16.0	22.4	–	73.0	5.8	–	–	–	–	–	19.2	32.0	2.8	
JOS	–	50.0	33.3	12.9	–	66.7	3.8	3.6	33.3	–	14.3	–	30.8	23.1	1.8	
HUE	14.3	52.6	–	36.7	–	80.0	10.9	17.9	40.6	–	–	–	22.2	29.5	2.0	
JIT	–	–	–	2.1	–	25.0	–	4.5	–	–	–	–	–	9.5	2.6	
MPO	3.4	43.5	–	0.0	–	17.1	0.0	3.1	22.2	55.1	–	0.0	4.0	13.0	1.2	
Corr. mean	12.1	42.0	11.1	11.0	–	48.4	3.2	7.4	34.5	51.4	6.3	8.0	10.6			
s.e.	1.6	1.8	1.6	1.0	–	2.1	0.6	1.3	1.6	2.8	1.0	2.2	1.4			
s.d.	6.3	6.3	5.8	2.7	–	7.6	2.0	3.6	5.3	5.7	3.1	2.7	5.8			
F.pr.	*	*	N.S.	***	–	***	*	***	*	*	**	***	N.S.			

Table 37. Provenance–locality mean tree pilodyn reading (mm) for 23 provenances of *Pinus oocarpa* / *P. patula* ssp. *tecunumanii* at 5 localities.

Prov	MEL	AGU	LDA	SPO	CCO	NBO	TUR	ANO	WIL	KBI	HBG	CPN	NDU	Corr. mean	s.e.
CAM	-	-	16.1	-	-	11.7	14.9	-	13.9	14.6	-	-	-	14.2	0.19
SUL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ZAP	-	-	15.3	-	-	11.4	13.1	-	12.5	-	-	-	-	13.2	0.21
MAR	-	-	-	-	-	11.9	-	-	-	-	-	-	-	13.8	0.44
CAN	-	-	14.5	-	-	-	-	-	12.5	13.5	-	-	-	13.0	0.25
LIM	-	-	-	-	-	11.1	-	-	-	-	-	-	-	13.0	0.44
CON	-	-	15.1	-	-	11.5	12.8	-	-	-	-	-	-	13.1	0.26
MQT	-	-	-	-	-	-	-	-	-	13.1	-	-	-	12.8	0.47
AGF	-	-	-	-	-	-	-	-	12.7	-	-	-	-	13.3	0.45
PUE	-	-	14.6	-	-	-	-	-	-	-	-	-	-	13.1	0.45
JUN	-	-	15.3	-	-	11.1	-	-	12.3	-	-	-	-	13.2	0.26
BON	-	-	14.2	-	-	11.5	13.2	-	-	-	-	-	-	12.9	0.26
BUC	-	-	14.6	-	-	11.6	13.0	-	-	13.5	-	-	-	13.0	0.22
ANG	-	-	14.8	-	-	-	14.2	-	13.0	-	-	-	-	13.5	0.26
ZAM	-	-	14.9	-	-	11.0	13.3	-	12.5	13.0	-	-	-	12.9	0.19
YUC	-	-	-	-	-	11.2	14.0	-	13.0	-	-	-	-	13.4	0.26
LAG	-	-	14.6	-	-	10.4	14.0	-	11.6	-	-	-	-	12.7	0.22
RAF	-	-	14.3	-	-	11.7	14.8	-	13.0	-	-	-	-	13.5	0.22
SIG	-	-	14.0	-	-	10.8	14.0	-	12.7	-	-	-	-	13.0	0.22
CHU	-	-	14.6	-	-	11.1	13.4	-	-	-	-	-	-	13.0	0.26
JOS	-	-	13.8	-	-	10.9	13.3	-	11.9	-	-	-	-	12.6	0.22
HUE	-	-	-	-	-	11.5	14.6	-	13.1	-	-	-	-	13.7	0.26
JIT	-	-	-	-	-	12.2	-	-	-	-	-	-	-	14.2	0.44
MPO	-	-	-	-	-	11.4	14.1	-	13.2	14.0	-	-	-	13.6	0.22
Corr. mean	-	-	14.8	-	-	11.3	13.8	-	12.7	13.6	-	-	-	-	-
s.e.	-	-	0.1	-	-	0.1	0.1	-	0.1	0.2	-	-	-	-	-
s.d.	-	-	0.5	-	-	0.3	0.4	-	0.3	0.4	-	-	-	-	-
F.pr.	-	-	N.S.	-	-	N.S.	*	-	***	*	-	-	-	-	-

Table 38. Provenance–locality mean tree basic density (g cm^{-3}) for 24 provenances of *Pinus oocarpa* / *P. patula* ssp. *tecunumanii* at 11 localities.

Prov	MEL	AGU	LDA	SPO	CCO	NBO	TUR	ANO	WIL	KBI	HBG	CPN	NDU	Corr. mean	s.e.
CAM	-	.416	-	-	.390	.468	.418	.413	.398	.376	.442	.410	.429	.409	.004
SUL	.426	-	-	-	-	-	-	-	-	-	-	-	-	.436	.011
ZAP	-	.421	-	-	.384	.478	.428	.419	.434	-	.437	-	.432	.415	.004
MAR	-	.431	-	-	-	.460	-	-	-	-	-	-	.426	.414	.011
CAN	-	-	-	-	.411	-	-	-	.414	.382	.440	.404	.437	.415	.004
LIM	-	.446	-	-	-	.474	-	-	-	-	-	-	-	.430	.013
CON	.417	-	-	-	-	.470	.421	.422	-	-	.465	-	.427	.429	.005
MQT	-	-	-	-	-	-	-	-	-	.391	-	.405	.437	.415	.008
AGF	-	-	-	-	-	-	-	.401	.412	-	-	-	-	.410	.009
PUE	-	.434	-	-	-	-	-	-	-	-	-	-	-	.419	.014
JUN	.411	-	-	-	-	.462	-	.380	.414	-	.458	-	.435	.420	.005
BON	.416	-	-	-	-	.458	.420	-	-	-	.462	-	.442	.428	.005
BUC	-	.418	-	-	-	.461	.411	.428	-	.408	.443	-	.430	.419	.004
ANG	-	.445	-	-	-	-	.405	-	.398	-	.438	-	.425	.410	.005
ZAM	-	-	-	-	.406	.517	.411	.406	.425	.402	.437	-	.449	.419	.004
YUC	-	-	-	-	.391	.450	.402	.422	.406	-	.428	.424	.428	.407	.004
LAG	-	.433	-	-	.403	.471	.435	.398	.412	-	.416	-	.445	.411	.004
RAF	.402	.420	-	-	-	.431	.402	.411	.406	-	.465	-	.418	.416	.004
SIG	-	.429	-	-	-	.463	.409	.386	.405	-	.429	.433	.439	.407	.004
CHU	-	-	-	-	-	.495	.427	-	-	-	-	-	.413	.423	.009
JOS	-	.449	-	-	-	.488	.428	.426	.422	-	.447	-	.425	.425	.005
HUE	-	.422	-	-	-	.467	.387	.389	.414	-	-	-	.395	.400	.006
JIT	-	-	-	-	.367	.440	-	.392	-	-	-	-	-	.386	.007
MPO	.400	.403	-	-	.391	.460	.406	.397	.404	.376	-	.383	.414	.403	.004
Corr. mean	.405	.430	-	-	.400	.468	.415	.410	.415	.391	.442	.416	.429	-	-
s.e.	.005	.004	-	-	.004	.007	.003	.004	.003	.004	.002	.008	.004	-	-
s.d.	.009	.013	-	-	.008	.017	.010	.011	.010	.008	.007	.020	.018	-	-
F.pr.	N.S.	N.S.	-	-	*	N.S.	N.S.	*	N.S.	N.S.	**	N.S.	N.S.	-	-

Table 39. Provenance–locality mean percentage of trees with α -pinene + β -pinene > 80% for 21 provenances of *Pinus oocarpa* / *P. patula* ssp. *tecunumanii* at 3 localities.

Prov	MEL	AGU	LDA	SPO	CCO	NBO	TUR	ANO	WIL	KBI	HBG	CPN	NDU	Corr. mean	s.e.
CAM	–	–	40.0	–	–	–	–	–	23.1	–	–	–	–	43.7	8.6
SUL	69.2	–	–	–	–	–	–	–	–	–	–	–	–	50.7	14.3
ZAP	70.0	–	45.5	–	–	–	–	–	45.5	–	–	–	–	56.9	6.5
MAR	78.6	–	–	–	–	–	–	–	–	–	–	–	–	61.7	14.7
CAN	–	–	5.6	–	–	–	–	–	55.0	–	–	–	–	39.8	8.0
LIM	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
CON	85.7	–	64.7	–	–	–	–	–	–	–	–	–	–	75.6	7.6
MQT	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
AGF	–	–	–	–	–	–	–	–	36.4	–	–	–	–	38.0	13.9
PUE	–	–	0.0	–	–	–	–	–	–	–	–	–	–	0.0	0.3
JUN	66.7	–	40.0	–	–	–	–	–	53.3	–	–	–	–	52.9	7.1
BON	26.7	–	7.7	–	–	–	–	–	–	–	–	–	–	15.9	6.6
BUC	33.3	–	44.4	–	–	–	–	–	–	–	–	–	–	42.2	9.0
ANG	–	–	35.7	–	–	–	–	–	50.0	–	–	–	–	51.3	8.2
ZAM	–	–	0.0	–	–	–	–	–	46.2	–	–	–	–	28.3	8.9
YUC	61.5	–	–	–	–	–	–	–	8.3	–	–	–	–	28.6	8.1
LAG	64.3	–	15.4	–	–	–	–	–	25.0	–	–	–	–	34.3	6.9
RAF	25.0	–	5.9	–	–	–	–	–	26.3	–	–	–	–	19.9	5.7
SIG	60.0	–	42.9	–	–	–	–	–	37.5	–	–	–	–	47.8	6.6
CHU	71.4	–	35.3	–	–	–	–	–	–	–	–	–	–	52.5	8.9
JOS	–	–	16.7	–	–	–	–	–	100.0	–	–	–	–	64.4	9.1
HUE	92.9	–	–	–	–	–	–	–	18.2	–	–	–	–	49.9	9.7
JIT	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
MPO	92.9	–	–	–	–	–	–	–	100.0	–	–	–	–	95.2	4.7
Corr. mean	61.4	–	31.6	–	–	–	–	–	44.8	–	–	–	–	–	–
s.e.	3.7	–	2.8	–	–	–	–	–	3.5	–	–	–	–	–	–
s.d.	12.0	–	–	–	–	–	–	–	11.0	–	–	–	–	–	–
F.pr.	N.S.	–	–	–	–	–	–	–	***	–	–	–	–	–	–

Table 40. Provenance–locality mean tree log ratio of α -pinene + β -pinene + β -phellandrene to Δ -3-carene for 21 provenances of *Pinus oocarpa* / *P. patula* ssp. *tecunumanii* at 3 localities.

Prov	MEL	AGU	LDA	SPO	CCO	NBO	TUR	ANO	WIL	KBI	HBG	CPN	NDU	Corr. mean	s.e.
CAM	–	–	2.72	–	–	–	–	–	1.61	–	–	–	–	2.15	0.79
SUL	5.01	–	–	–	–	–	–	–	–	–	–	–	–	5.03	1.13
ZAP	3.06	–	4.61	–	–	–	–	–	4.89	–	–	–	–	4.18	0.63
MAR	4.57	–	–	–	–	–	–	–	–	–	–	–	–	4.59	1.13
CAN	–	–	4.64	–	–	–	–	–	5.12	–	–	–	–	4.87	0.79
LIM	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
CON	4.66	–	5.02	–	–	–	–	–	–	–	–	–	–	4.75	0.79
MQT	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
AGF	–	–	–	–	–	–	–	–	4.88	–	–	–	–	5.06	1.13
PUE	–	–	4.60	–	–	–	–	–	–	–	–	–	–	4.40	1.13
JUN	4.08	–	4.28	–	–	–	–	–	4.43	–	–	–	–	4.26	0.63
BON	3.09	–	2.78	–	–	–	–	–	–	–	–	–	–	2.85	0.79
BUC	1.12	–	4.98	–	–	–	–	–	–	–	–	–	–	2.97	0.79
ANG	–	–	4.54	–	–	–	–	–	4.31	–	–	–	–	4.42	0.79
ZAM	–	–	4.56	–	–	–	–	–	4.72	–	–	–	–	4.63	0.79
YUC	4.12	–	–	–	–	–	–	–	–0.59	–	–	–	–	1.86	0.79
LAG	2.49	–	1.34	–	–	–	–	–	1.35	–	–	–	–	1.72	0.63
RAF	–0.43	–	–0.27	–	–	–	–	–	0.53	–	–	–	–	–0.06	0.63
SIG	4.01	–	4.65	–	–	–	–	–	3.76	–	–	–	–	4.14	0.63
CHU	4.70	–	4.91	–	–	–	–	–	–	–	–	–	–	4.72	0.79
JOS	–	–	4.22	–	–	–	–	–	5.11	–	–	–	–	4.65	0.79
HUE	4.53	–	–	–	–	–	–	–	3.12	–	–	–	–	3.92	0.79
JIT	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
MPO	4.22	–	–	–	–	–	–	–	4.74	–	–	–	–	4.58	0.79
Corr. mean	3.78	–	3.99	–	–	–	–	–	3.62	–	–	–	–	–	–
s.e.	0.33	–	0.31	–	–	–	–	–	0.33	–	–	–	–	–	–
s.d.	0.46	–	0.36	–	–	–	–	–	0.61	–	–	–	–	–	–
F.pr.	***	–	***	–	–	–	–	–	***	–	–	–	–	–	–

7. Discussion

7.1 Provenance representation

P. caribaea

The natural distribution of *P. caribaea* var. *hondurensis* has been well covered in these provenance trials with the following potentially interesting exceptions, the existence of most of which was not widely known when the seed collections were being made.

- i) Stands in the western-most part of the Department of Zelaya in Nicaragua (Waswala) to the south-east of Santa Clara across the Cordillera Isabella (approximate location 13°20'N, 85°15'W) (Hughes, pers. comm.)
- ii) The southern-most occurrences in Honduras in the relatively dry Rio Goascoran Valley, one of the few river systems that drains to the Pacific in which it occurs (approximate location 14°03'N, 87°38'W) (Robbins & Hughes, 1983).
- iii) Isolated occurrences in hardwood forest between the Rio Patuca and the Montañas de Colon in the Gracias a Dios Department of Honduras (approximate location 15°00'N, 84°45'W) (Robbins & Hughes, 1983).
- iv) A very limited occurrence at El Pinal (near Tical), Department of Peten, Guatemala (approximate location 17°15'N, 89°37'W) (Anon, 1987)
- v) Isolated occurrence at Ejido Coaba, Department of Quintana Roo, Mexico (approximate location 19°40'N, 88°30'W) (Chavelos Polito, 1981)
- vi) The remnant populations on Roalan Island, Honduras (approximate location 16°25'N, 86°40'W)

P. caribaea var. *bahamensis* was represented only by one provenance from Andros Island. The islands of the group on which it occurs are far enough apart for there to be a likelihood of genetic differences (Barnes, 1986a) and those missing from these trials are:

- i) Grand Bahama
- ii) Abaco
- iii) New Providence
- iv) North Caicos
- v) Middle Caicos

P. caribaea var. *caribaea* was well represented only in one trial but the indications have been that there is little provenance variation in the sources from the main island of Cuba. However, there was no representation from Isla de Pinos, which is sufficiently distant from the main island to have genetically distinct populations.

P. oocarpa

The natural distribution of *P. oocarpa* in Central America is more continuous than that of *P. caribaea* var. *hondurensis* and the provenance coverage in the trials is likely to be satisfactory to estimate the population variation. It must be pointed out however that more than half the natural distribution of *P. oocarpa* occurs outside Central America in Mexico and that there is no representation to cover that extended range.

P. patula ssp. *tecunumanii*

When *P. patula* ssp. *tecunumanii* was recognized as separate from *P. oocarpa* in the trials, it was realized that provenance representation in this second taxon was very sparse. This species is confined mainly to higher altitudes than *P. oocarpa* (although there are some extraordinary exceptions) and is associated with mountains that form "islands" in the landscape. It therefore has a very discontinuous distribution and the four provenances distinguished in this "*P. oocarpa*" collection constitute only a sparse sampling of *P. patula* ssp. *tecunumanii*. A satisfactory sampling would include the following sources in addition to the four represented viz. Rafael, Yucul and Camelias from Nicaragua and Mountain Pine Ridge from Belize (see Styles & McCarter, 1988):

i) Las Botijas, Comayagua (Honduras)	14°22'N	87°24'W	1550 m
ii) Siguatepeque, Comayagua (Honduras)	14°33'N	87°50'W	1400 m
iii) Villa Santa, El Paraiso (Honduras)	14°11'N	86°20'W	900 m
iv) Guajiquiro, La Paz (Honduras)	14°11'N	87°50'W	2000 m
v) La Paz, La Paz (Honduras)	14°19'N	87°50'W	1850 m
vi) Culmi, Olancho (Honduras)	15°06'N	85°21'W	600 m
vii) La Colonia, Olancho (Honduras)	15°15'N	85°20'W	600 m
viii) Cusuco, Cortes (Honduras)	15°30'N	88°11'W	1600 m
ix) Montaña Sumpul, Ocotepeque (Honduras)	14°24'N	89°08'W	1900 m
x) Montaña Celaque, Lempira, (Honduras)	14°34'N	88°39'W	1700 m
xi) San Esteban, Olancho (Honduras)	15°22'N	85°36'W	750 m
xii) San Francisco de la Paz, Olancho (Honduras)	15°05'N	86°20'W	1000 m
xiii) Belen Gualcho, Ocotepeque (Honduras)	14°28'N	88°50'W	1800 m
xiv) Jocon, Yoro (Honduras)	16°16'N	86°54'W	1000 m
xv) San Pastor Pine Ridge, Cayo (Belize)	16°41'N	88°58'W	700 m
xvi) La Soledad, Jalapa (Guatemala)	14°31'N	90°15'W	2400 m
xvii) San Jeronimo, Baja Verapaz (Guatemala)	15°03'N	90°18'W	1850 m
xviii) Finca Las Victorias, Zacapa (Guatemala)	15°12'N	89°22'W	950 m

7.2 Trial site coverage

Even though trials for inclusion in the coordinated assessment programme were selected to cover the whole range of environments over which the species might be grown, when criteria such as provenance representation, age, condition, site uniformity etc. were applied, the number that could be used was reduced from many hundreds to less than twenty trials for each species. The eventual set provided satisfactory climatic, if not edaphic coverage for *P. caribaea* var. *hondurensis* but most sites were too tropical for vars. *bahamensis* and *caribaea* to show their full potential. Both the latter are best adapted to a narrow climatic range where conditions are either too temperate for the var. *hondurensis* or too tropical for *P. elliottii* Engelm.

The set of *P. oocarpa*/*P. patula* ssp. *tecunumanii* trials provided a reasonable range of environments over which to test the species although trials tended to be sited alongside those of *P. caribaea* and there was consequently a bias towards sites that were too tropical.

7.3 Provenance variation

Pinus caribaea

Productivity

In the majority of trials there were no significant differences between provenances for survival (Table 5). In all but one of the trials in which differences were significant, this was due to the higher establishment failures for the var. *caribaea*, particularly where the environment was drier and/or hotter and where overall trial survival was lower. This reflects the vulnerability of var. *caribaea* in these circumstances due to it being naturally less well adapted to tropical conditions than var. *hondurensis* and due also to its very much less vigorous early growth.

There were highly significant differences in height (Table 6), diameter (Table 7) and volume under bark (Table 9). All provenances of vars. *hondurensis* convincingly outperformed those of the vars. *bahamensis* and *caribaea*. The best performer across sites among the var. *hondurensis* provenances was Byfield seed orchard (Queensland) which itself was based on a population of Mountain Pine Ridge (Belize) origin. This latter provenance was not, however, the best performer among the natural sources. First in this respect was the coastal provenance, Laguna del Pinar (Nicaragua). If this result is discounted, because it was represented in only two trials, the best performer across a large number of localities was Guanaja (Honduras), the only island source of var. *hondurensis*. Among the coastal provenances, Alamicamba (Nicaragua) came nearest to approaching the outstanding performance of Laguna del Pinar. First among the inland sources was Santa Clara (Nicaragua), which ranked third overall among the natural provenances, closely followed by Potosi (Honduras). Santos (Belize) was the poorest.

Guanaja had the thickest bark (Table 8) and also the highest proportion of bark (Table 10) when taken as a percentage of total tree volume. In contrast, the coastal sources had low values for both bark traits. The best inland sources for wood production generally had the highest bark volumes with the exception of Limones (Honduras) which had low wood production but relatively very thick bark.

Gibson (1982) found no major genotype-environment interaction effects in the productivity traits. However, when the full table is examined, there are some severe reversals in ranking, e.g. Mountain Pine Ridge was top at kwaMbonambi (South Africa) but ranked near the bottom at San Pedro (Ivory Coast). Some caution is also advised in interpreting the early performance of var. *caribaea*. When planted in its optimum environment, it can start to outperform var. *hondurensis* after 15 to 20 years which may be too late in a pulpwood rotation but would be significant in a sawlog rotation. In making decisions, therefore, as to which provenances might perform best under particular conditions, the reader should temper the general conclusions given here with an interpretation of provenance performance in the individual trials that have environmental conditions closest to his or her own.

Stem quality

The slower-growing var. *caribaea* and var. *bahamensis* provenances had straighter stems (Table 11) than any of the var. *hondurensis*, except for the genetically improved Byfield seed orchard (Queensland) source. This result would be expected given the evident strong genetic control of this trait. Otherwise, the main point of interest is the better stem form of the group of coastal provenances compared to those from inland with the exception of Santa Clara (Nicaragua).

Stem lean (Table 12) could be taken as an indication of wind firmness in the face of cyclonic storms. Most of the var. *caribaea* provenances are outstanding for this trait; they are followed by the coastal provenances of var. *hondurensis* and then the inland provenances. The single var. *bahamensis* provenance is not as good as those of var. *caribaea*. Guanaja (Honduras) performed particularly poorly in this respect, which is surprising given that it is an island source. Otherwise, wind firmness appeared to be well correlated with the frequency and severity of cyclones in the region of the provenance's natural occurrence. The greater than expected susceptibility of var. *bahamensis* in this respect was probably due to its shallow rooting habit, a special adaptation to growing on almost pure limestone rock in the Bahamas, but an attribute that may not fit it well to wind firmness when growing on deep soils.

Multiple stems and forks (Table 13) generally followed the same pattern as stem lean, with fewest in var. *caribaea*, next fewest in the coastal provenances of var. *hondurensis* and var. *bahamensis* and highest numbers in the inland provenances of var. *hondurensis*.

Branching

All the provenances of *P. caribaea* var. *caribaea* had higher numbers of branches per whorl (Table 14) than all provenances of var. *hondurensis* and var. *bahamensis* between which there was little difference. The same applied for the number of whorls per unit length of stem (Table 15) except that the coastal provenances of var. *hondurensis* had consistently fewer whorls than the inland provenances. The length of the longest internode (Table 16) (an indication of foxtailing) showed similar trends with var. *caribaea* least susceptible and the coastal provenances of var. *hondurensis* most prone to this defect. For these three traits, var. *bahamensis* tended to rank with inland var. *hondurensis* rather than with var. *caribaea*. Var. *caribaea* had finer branches (Table 17) than var. *bahamensis* which in turn had finer branches than var. *hondurensis*. Differences between provenances of var. *hondurensis* for this trait were not great but the Byfield seed orchard (Queensland) source had the finest branches in this variety and this no doubt reflects selection pressure that had been brought to bear on this particular trait. The highly significant differences between provenances and the absence of *gei* indicate the strong genetic control over branching characteristics as has been found in other work on tropical pines, (e.g. Barnes & Schweppenhauser, 1979).

Reproduction

The "flowering" traits (Table 18) have been analysed in detail by Gibson *et al.*, (1983b). Highly significant provenance differences were identified and inland provenances of *P. caribaea* var. *hondurensis* were better producers than lowland provenances. Particularly prolific were the upland provenances Culmi, Santa Clara, Potosi, and Mountain Pine Ridge and its derived landrace Byfield, from Queensland, Australia. Very few cones were produced by vars. *caribaea* and *bahamensis* and the insular Guanaja provenance of var. *hondurensis*. Strobilus productivity was generally low or non-existent in sub-tropical locations where the mean annual temperature is below 21°C and the mean daily temperature in the hottest month below 26°C. Coning was most prolific where the mean annual temperature is about

24°C. When the mean annual temperature exceeds 26°C, abnormalities in flowering periodicity and synchronization of male and female strobilus production suggested that the presence of strobili should not be taken as indicative of potential seed production. There was a small but significant interaction between environment and the lowland and upland groups of provenances.

Wood density

Wood density analyses have been reported elsewhere (e.g. Barnes *et al.*, 1983; Wright *et al.*, 1986, 1987). The pilodyn test (Table 19) was carried out in only five trials and therefore comparison with the wood basic density (Table 20) can only be superficial. Both traits show a general trend for the var. *caribaea* provenances to have the highest density results followed by the inland and then the coastal provenances of var. *hondurensis*. The one outstanding exception was the Guanaja (Honduras) provenance of var. *hondurensis* which had a density that was as high as the denser provenances of var. *caribaea*. The density of var. *bahamensis* was low at all localities. This is in contrast to the data given in the pilodyn table when penetration was least (indicating high density) for var. *bahamensis*. However, pilodyn assessment for var. *bahamensis* was only made at one locality, Loudima (Congo), and basic density was also highest in this trial, no doubt inflated by the very low growth rate of this variety when almost on the equator. In less tropical environments however (where it would be expected to be better adapted), the wood density of var. *bahamensis* has been found to be consistently higher than that of var. *hondurensis* (Barnes *et al.*, 1977).

Within species, gei in wood density of tropical pines has been found to be negligible (e.g. Barnes *et al.*, 1977; Barnes *et al.*, 1983; Wright *et al.*, 1986, 1987). It appears, however, that this does not necessarily hold for varieties within species, as indicated here in Table 20 for *P. caribaea*, or between species.

Turpentine composition

Although there were significant differences between provenances for the proportion of α - and β -pinenes in the oleoresin (Table 21) at two of the three localities sampled, consistency of ranking between trials was surprisingly low. This could have been because of the narrow range of means for the majority of var. *hondurensis* provenances and the possibility that a sample from only five trees per plot did not give a sufficiently stable mean. More surprising was the large variation (25.8 to 56.2%) for the locality means corrected for provenances. This indication of environmental influence on terpene composition substantiated the caution advised by Birks & Kanowski (1988) in deducing the extent and mode of genetic control from compositional data.

For the trait expressing the ratio α - + β -pinene + β -phellandrene to Δ -3-carene (Table 22), there was greater consistency of ranking within localities and between overall means for trials. There were lower ratios for var. *caribaea* than there were for var. *hondurensis*.

P. oocarpa and *P. patula* ssp. *tecunumanii*

Since these two species are integral parts of the same trials, they are discussed together below.

Productivity

Although there were significant differences in survival (Table 23) at four localities, the corrected means for provenances across trials indicate that these were very small overall. There was no difference between the two species.

There were significant differences between provenances either for height (Table 24) or for diameter (Table 25), mostly for both, at all localities, and consequently also for under bark volume (Table 26) at most. The four sources of *P. patula* ssp. *tecunumanii* – Cameliás (Nicaragua), Yucul (Nicaragua), Rafael (Nicaragua) and Mountain Pine Ridge (Belize) – were outstandingly the best provenances for height and volume, and also stem taper, in most localities. Disregarding Sullates (Nicaragua) which occurred in only one trial and is also suspected of being *P. patula* ssp. *tecunumanii* (C.E. Hughes, pers. comm.), the best overall performers among the *P. oocarpa* provenances were Pueblo Caido (Guatemala), Lima (Guatemala), Bonete (Nicaragua), Conacaste (Guatemala), Agua Fria (Honduras) and Canas (Guatemala). The four Guatemalan provenances originated from sources that were geographically very close to each other in the north eastern part of its range in that country. Although the two Nicaraguan provenances were not as well represented in the trials, they

must be recognized as potentially good performers, as must Agua Fria from Honduras. It is not possible, therefore, to infer that *P. oocarpa* provenances from Central America are likely to perform any better if they come from a particular part of the species' range, other than to say that the weight of evidence is that the provenances around Coban in Guatemala are likely to be good whereas those in the eastern-most part of Guatemala are likely to be among the poorest.

The *P. patula* ssp. *tecunumanii* provenances, particularly those from Mountain Pine Ridge (Belize), tended to have thinner bark (Table 27) than *P. oocarpa*. Bark percentage (Table 28) was lower in all the *P. patula* ssp. *tecunumanii* provenances (28.0 to 31.2) than in the *P. oocarpa* provenances (33.0–39.6), but there was little difference within species.

Stem quality

Three of the four provenances of *P. patula* ssp. *tecunumanii* – Rafael, Yucul and Camelias – had the best stem form (Table 29). Mountain Pine Ridge, however, ranked with the lower *P. oocarpa* provenances among which the differences were not great except that the northwestern-most source was poorest.

Stem lean (Table 30) was quite pronounced overall and this reflected the lack of wind-firmness in both species when planted on cyclone-susceptible sites, on most of which the coastal provenances of *P. caribaea* would have been better adapted. Among the *P. oocarpa* provenances, Lagunilla (Guatemala) had least lean and it also ranked high for straightness; but it ranked worst for multiple stems and forks, a feature more common in *P. oocarpa* than *P. patula* ssp. *tecunumanii*.

Branching

The four provenances of *P. patula* ssp. *tecunumanii* had the highest number of branches per whorl (Table 32), generally the lowest number of whorls per unit length of stem (Table 33) and the longest internodes (Table 34) i.e. tendency to foxtail. The longest internodes by a considerable margin, were in the Mountain Pine Ridge provenance of *P. patula* ssp. *tecunumanii*. This is a trait that is more often associated with *P. caribaea* than with *P. oocarpa* or *P. patula* ssp. *tecunumanii*. This, taken together with the ease with which the artificial hybrid can be made between the Mountain Pine Ridge provenances of *P. patula* ssp. *tecunumanii* and *P. caribaea* var. *hondurensis* (Nikles, 1990), suggests that a natural hybridization between the two species may have occurred in the past to produce the present day Mountain Pine Ridge *P. patula* ssp. *tecunumanii*. This provenance was also among those with the coarsest branching (Table 35), as were the two northwestern-most sources of *P. oocarpa*.

Reproduction

Most of the *P. oocarpa* coned more profusely than did the four provenances of *P. patula* ssp. *tecunumanii* (Table 36). Among the *P. oocarpa* provenances, the seven from Honduras were all shy coners compared with all but two of the nine provenances from Guatemala which, together with the southern-most two provenances from Nicaragua, were high producers. Generally, coning was more frequent at trial sites that were most distant from the equator.

Wood density

The data for pilodyn penetration (Table 37) and basic density (Table 38) indicate that, despite their significantly greater volume production, the *P. patula* ssp. *tecunumanii* provenances had, on average, only marginally lower wood density than those of *P. oocarpa*, viz. 0.409 compared with 0.415 g cm⁻³ respectively. If those provenances that were poorly represented are omitted, there is only small variation in density. Similarly, the effects of age and growth are confounded with density and this makes comparison between sites difficult. Generally, there appears to be little variation between sites with the exception of Nabou (Fiji) where the average density was highest although the poor stem straightness and higher than average amount of stem lean may have resulted in more high density compression wood.

Turpentine composition

The Mountain Pine Ridge provenance was prominent for high α - and β -pinene percentage (Table 39). This again sets this source apart from the other provenances of *P. patula* ssp.

tecunumanii, which had values in the mid *P. oocarpa* range and again suggests that there may be some *P. caribaea* influence in it. Provenance values were inconsistent in their rankings across sites and site means were themselves variable. This probably reflects the considerable tree to tree variation and the need to sample far more trees to get a stable plot mean.

For α - + β -pinene + β -phellandrene expressed as a ratio with Δ -3-carene (Table 40), there was much greater consistency both among provenances within sites and between sites. The Nicaraguan provenances of *P. patula* ssp. *tecunumanii* had very low values because of the relatively high proportion of Δ -3-carene in their turpentine. The Mountain Pine Ridge source of this species was again anomalous in that it appeared to be more like *P. oocarpa* or *P. caribaea*. Among the *P. oocarpa* provenances, Lagunilla (Guatemala) was anomalous and more like *P. patula* ssp. *tecunumanii* in this trait.

8. Conclusions and recommendations

8.1 Provenance variation

P. caribaea

Five major groups emerged from the analysis of the data for *P. caribaea* viz.

1. *P. caribaea* var. *caribaea*
2. *P. caribaea* var. *bahamensis*
- 3.a *P. caribaea* var. *hondurensis* – coastal sources
- b *P. caribaea* var. *hondurensis* – inland sources
- c *P. caribaea* var. *hondurensis* – the insular source.

P. caribaea var. *caribaea* had excellent stem straightness, wind-firmness and branching architecture and high wood density. It is also resistant to the lepidopterous shoot-borers of Southeast Asia. However, it had low survival and inferior early growth rate particularly in more tropical conditions.

P. caribaea var. *bahamensis* had attributes very similar to those of var. *caribaea* but it was less wind-firm and generally slightly under-performed the latter variety except in early growth rate. However, var. *bahamensis* was poorly represented and few if any trials were in climatic or edaphic environments that were suited to its special adaptive attributes.

P. caribaea var. *hondurensis* of coastal origin had good growth rate, moderately good stem form, thin bark, and was wind firm. Its branching characteristics were good except that it was inclined to foxtail. Its worst feature was low wood density. It is seriously susceptible to shootmoth attack in Southeast Asia.

P. caribaea var. *hondurensis* of inland origin was very variable in productivity with most provenances ranking low but a few ranking very high. It had higher wood density than coastal sources, less tendency to foxtail and it was the most precocious and prolific in its coning habit. Stem straightness, wind firmness and branching traits were not as good as coastal sources and it is no more resistant to shoot borer.

P. caribaea var. *hondurensis* of insular origin (Guanaja) was outstanding in production and wood density, but lacked wind firmness, and was comparatively crooked and coarsely branched. It is not resistant to the shootmoth.

P. oocarpa and *P. patula* ssp. *tecunumanii*.

In addition to the obvious separate grouping of the *P. oocarpa* and *P. patula* ssp. *tecunumanii* provenances for most traits, the data suggested further divisions within species as follows:

- 1.a *P. oocarpa* – Mexican type (Huehuetenango, Guatemala, and Jitotol, Mexico);
- b *P. oocarpa* – Guatemala northern provenances;
- c *P. oocarpa* – Guatemala southern provenance (Lagunilla);
- d *P. oocarpa* – Honduras/Nicaragua provenances;
- 2.a *P. patula* ssp. *tecunumanii* – Nicaragua;
- b *P. patula* ssp. *tecunumanii* – Belize (Mountain Pine Ridge).

All the *P. patula* ssp. *tecunumanii* provenances were more productive than those of *P. oocarpa*. They also generally had thinner bark, straighter stems, fewer forks, fewer multiple stems, fewer branches, longer internodes, fewer cones, lightly lower wood density, lower α - and β -pinene and higher Δ -3-carene proportions. It has been found, however, that they are

more susceptible to attack by black aphids (Barnes & Styles, 1983) but *P. oocarpa* suffers worse damage from wild pigs (Sniezko & Mullin, 1987).

Among the *P. patula* ssp. *tecunumanii*, the three Nicaraguan provenances performed similarly for almost all traits. The Mountain Pine Ridge source (Belize) did deviate notably in having fewer and coarser branches, a greater tendency to foxtail, higher α - and β -pinene and lower Δ -3-carene proportions.

In *P. oocarpa*, the provenances of the northwest of Guatemala were slow-growing with poorer stem form and coarser branches. This is typical of Mexican sources of this species that have been tested in the past as exotics over a wide range of sites (Barrett & Mullin, 1968; Poynton, 1979). The northern Guatemalan provenances were distinguished from the Honduran provenances only by their more profuse flowering. The southern Guatemalan population, represented only by Lagunilla, was distinctive in a number of characteristics including thin bark, straight stems, wind firmness, high forking frequency, few branches but short internodes, and few cones. Some of these traits strengthened its resemblance to *P. patula* ssp. *tecunumanii* and some diminished its similarity to this species.

8.2 Provenance-environment interaction

No generalizations have been drawn from this data about consistent changes in rank with specific factors of the environment for any trait at the sub-specific level. The exception has been in *P. caribaea* var. *hondurensis* where there was some indication that coastal sources could be relatively more productive in low latitude, low altitude sites, particularly if these were susceptible to high winds. The coastal provenances were also relatively less precocious and prolific in cone production in cooler environments and more inclined to foxtail where conditions were conducive to continuous growth. Given the huge climate range in the natural distribution of *P. patula* ssp. *tecunumanii*, some provenance-environment interaction effects in this species may be expected when it is fully tested.

8.3 Species-environment interaction

These trials were not designed to compare species performance or even to provide a comparison between the varieties of *P. caribaea*. However, some general conclusions can be drawn on gei at these levels. Given a seasonal summer-maximum rainfall regime and no frost, an indication of the range of temperature and rainfall conditions required by each of the above taxa is given in Table 41 below. Taken over this whole range of climatic conditions, marked species-environment interaction can be expected caused by the effects of rainfall, temperature and wind.

Table 41. Temperature and rainfall requirements for *Pinus caribaea* vars. *hondurensis* and *bahamensis*, *P. oocarpa* and *P. patula* ssp. *tecunumanii*.

Species	Mean annual temperature (°C)													Mean annual rainfall (mm)									
	15	16	17	18	19	20	21	22	23	24	25	26	27	1000	1250	1500	1750	2000					
<i>P. caribaea</i> var. <i>hondurensis</i>								x	x	x	x	x	x		x		x		x		x		
<i>P. caribaea</i> var. <i>caribaea</i>								x	x	x	x	x					x		x				
<i>P. caribaea</i> var. <i>bahamensis</i>			x	x	x	x	x	x	x	x	x					x		x		x			
<i>P. oocarpa</i>					x	x	x	x	x	x						x		x		x			
<i>P. patula</i> ssp. <i>tecunumanii</i>	x	x	x	x	x	x	x	x	x	x	x	x					x		x		x		x

Fertile soils, combined with high rainfall, high temperatures and ill-defined seasons, produce an environment that is unsuitable for all these tropical pines because their relatively light crowns, particularly in the case of *P. oocarpa*, make site capture from vigorous competing natural woody regrowth impossible. All thrive better on lighter, less fertile, well-drained, sandy to sandy-loam soils and a marked dry season and, except for coastal *P. caribaea* var. *hondurensis*, a difference of at least 4°C in the mean daily temperatures of the warmest and coldest months.

Pest and disease factors in the environment, for example shoot moths, (*Dioryctria* and *Rhyacionia* species) on *P. caribaea* var. *hondurensis* and the black aphid (*Cinara cronartii* Tissot & Pepper) on *P. patula* ssp. *tecunumanii*, could introduce species-environment

interaction effects within the zones in which the species' environmental requirements overlap.

8.4 Future genetic development

A broad cross section of provenances of *P. caribaea* and *P. oocarpa* has been tested in these trials over a wide range of exotic environments. The main deficiencies in representation are now being covered by new international programmes for each species (Baylis & Barnes, 1990, and Crockford *et al.*, 1990, respectively) leaving just a few populations *P. caribaea* vars. *hondurensis* and *caribaea* that have not yet been tested widely. Early analyses indicate that a very large proportion of the variation in most traits is within provenance and that structure at the family level is required in the experiments to partition the variance further before it can be fully explained and utilized for genetic development (Gibson *et al.*, 1983a). This is being done in second-stage international provenance trials in which seed from selected natural provenances is kept separate by individual mother trees (Crockford *et al.*, 1990). In the meantime, selections in some of the trials themselves are being used for the clonal assembly of regional breeding populations (Pottinger & Barnes, 1990). The trials have provided data from which it has been possible to detect broad regional genetic differences. Genetic differences clearly also exist within these regions but much more sensitive sampling strategies, and experiments that are designed to provide information on parent population structure, levels of neighbourhood inbreeding, individual seed-tree selection criteria, and family-within-provenance variation, would be necessary to gain a fundamental understanding of their size and nature. In addition, an investigation of the chloroplast DNA restriction fragment patterns (see e.g. Szmidt *et al.*, 1988) of these species could indicate finer groupings of the provenances that might lead to more efficient recognition and use of the variation in them. Nevertheless, the utilization of the information on the broad differences indicated above together with empirical use of the data provided for individual trials in these tables can lead to economically highly significant operational gains, merely through selection of the correct provenance region (Plumptre & Barnes, 1982). The advances will be even greater if the discovered attributes of the different provenances are enhanced and combined to create synthetic varieties, as they could be for example through the use of multiple population breeding strategies (Namkoong *et al.*, 1980; Barnes, 1986).

References

- BARNES, R.D. (1986a). Forest genetics and seed production in *Pinus caribaea* var. *bahamensis* in the Bahamas. *FAO Technical Report*, No. UTF/BHA/OO3/BHA, 36 pp.
- BARNES, R.D. (1986b). Multiple population tree breeding in Zimbabwe. In *Proceedings in IUFRO Conference - Joint meeting of Working Parties on breeding theory, progeny testing and seed orchards*. Williamsburg, Virginia. October 13-17, 1986. The North Carolina State University - Industry Cooperation Tree Improvement Program. 285-297.
- BARNES, R.D., & GIBSON, G.L. [EDITORS] (1984a). Provenance and genetic improvement strategies in tropical forest trees. *Proceedings of a Joint Work Conference on Provenance and Genetic Improvement Strategies in Tropical Forest Trees*, held in Mutare, Zimbabwe, 9-14 April, 1984 by IUFRO Working Parties S2.02-08 Tropical species provenances, S2.03-01 Breeding Tropical Species, S2.03-13 Breeding Southern pines. Commonwealth Forestry Institute, Oxford, UK and Zimbabwe Forestry Commission, Harare, Zimbabwe. 663 pp.
- BARNES, R.D. & GIBSON, G.L. (1984b). Experimental design, management and selection traits in provenance trials of tropical pines. In *Provenance and genetic improvement strategies in tropical forest trees*. Mutare, Zimbabwe, April, 1984. [edited by Barnes, R.D., & Gibson, G.L.] Commonwealth Forestry Institute, Oxford, and Forest Research Centre, Harare. 8-22.
- BARNES, R.D., & SCHWEPENHAUSER, M.A. (1979). *Pinus patula* Schiede & Deppe progeny tests in Zimbabwe-Rhodesia: genetic control of 1.5-year-old traits and a comparison of progeny test methods. *Silvae Genetica* 28, 156-167.
- BARNES, R.D., & STYLES, B.T. (1983). The closed-cone pines of Mexico and Central America. *Commonwealth Forestry Review* 62 (2) 81-84.
- BARNES, R.D., BURLEY, J., GIBSON, G.L., GARCIA DE LEON, J.P. (1984). Genotype-environment interactions in tropical pines and their effects on the structure of breeding populations. *Silvae Genetica* 33, 186-198.
- BARNES, R.D., GIBSON, G.L., BARDEY, M-A. (1983). Variation and genotype-environment interaction in international provenance trials of *Pinus caribaea* var. *hondurensis* and implications for population improvement strategy. *Silvicultura* 8 (29) 35-43.
- BARNES, R.D., WOODEND, J.J., SCHWEPENHAUSER, M.A., MULLIN, L.J. (1977). Variation in diameter growth and wood density in six-year-old provenance trials of *Pinus caribaea* Morelet on five sites in Rhodesia. *Silvae Genetica* 26, 163-7.
- BAYLIS, B.W.H., & BARNES, R.D. (1990). International provenance trial of *Pinus caribaea* var. *bahamensis*. In *Breeding tropical trees: population structure and genetic improvement strategies in clonal and seedling forestry*, Pattaya, Thailand, 28 November-3 December 1988. [edited by Gibson, G.L., Griffin, A.R., Matheson, A.C.] Oxford Forestry Institute and Winrock International. 363-409.
- BARRETT, R.G., & MULLIN, L.J. (1968). A review of forest trees in Rhodesia. *The Rhodesia Bulletin of Forestry Research, Rhodesia Forestry Commission* No. 1 227 pp.
- BIRKS, J.S., & BARNES, R.D. (1985). Multivariate analysis of data from international provenance trials of *Pinus oocarpa*/*Pinus patula* ssp. *tecunumanii*. *Commonwealth Forestry Review* 64 (4) 367-374.
- BIRKS, J.S. & KANOWSKI, P.J. (1988). Interpretation of the composition of coniferous resin. *Silvae Genetica* 37, 29-39.
- BRIDGEN, L.G., BARNES, R.D., GIBSON, G.L. (1983). Provenance tests of *Pinus caribaea* in the Northern Territory, Australia - six-year assessments. *Silvicultura* 8 (29) 45-48.
- BURLEY, J. & GREEN, C.L. (1978). Relationships of terpenes between exotic and natural populations of *Pinus caribaea* Morelet and *P. oocarpa* Schiede. In *Proceedings of the Conference on Biochemical genetics of forest trees*, Umeå, Sweden 1978. [edited by Rudin, D.] Department of Forest Genetics and Plant Physiology, Umeå, Sweden. 118-135.
- BURLEY, J., & NIKLES, D.G. [EDITORS] (1972). Selection and breeding to improve some tropical conifers. Vol. I. Commonwealth Forestry Institute, Oxford, UK and Department of Forestry, Queensland, Australia. 417 pp.
- BURLEY, J., & NIKLES D.G. [EDITORS] (1973a). Selection and breeding to improve some tropical conifers. Vol. II. Commonwealth Forestry Institute, Oxford, UK and Department of Forestry, Queensland, Australia. 466 pp.
- BURLEY, J., & NIKLES, D.G. [EDITORS] (1973b). Tropical provenance and progeny research and international cooperation. *Proceedings of a Joint Meeting on Tropical Progeny Research and International Cooperation held in Nairobi, Kenya, 22-26 October, 1973* by IUFRO Working Parties S2.02.08 Tropical species provenances, S2.03.1 Breeding tropical and subtropical species. Commonwealth Forestry Institute, Oxford, UK. 597 pp.
- CAMCORE (1987). *Camcore News*, College of Forest Resources, North Carolina State University No. 5, 15 pp.
- CHAVELOS POLITO, J. (1981). El *Pinus caribaea* Morelet en el estado de Quintana Roo, Mexico. *Nota Tecnica, Instituto de Investigacion Forestal, Mexico D. F.*, Mexico No. 10, 8 pp.
- CROCKFORD, K.J., BIRKS, J.S., BARNES, R.D. (1990). Family-within-provenance trials of *Pinus caribaea*, *P. oocarpa* and *P. patula* ssp. *tecunumanii* - Early results and implications for breeding strategy. In *Breeding tropical trees: population structure and genetic improvement strategies in clonal and seedling forestry*, Pattaya, Thailand, 28 November-3 December 1988. [edited by Gibson, G.L., Griffin, A.R., Matheson, A.C.] Oxford Forestry Institute and Winrock International. 176-186.
- EISEMANN, R.L., NIKLES, D.G. NEWTON, R.S. (1983). Preliminary investigation of variation and provenance-environment interaction in *Pinus caribaea* var. *hondurensis* in Queensland plantings of the international provenance trials. *Silvicultura* 8 (29) 62-68.
- FERNANDEZ DE LA REGUERA, P.A., BURLEY, J., MARRIOTT, F.H. (1986). Putative hybridization between *P. caribaea* Morelet and *P. oocarpa* Schiede: a canonical approach. *Silvae Genetica* 37, 88-93.
- FERNANDEZ DE LA REGUERA, P.A., MARRIOTT, F.H.C., BURLEY, J. (1988) Multiple set canonical analysis: an application to forestry genetics. *Biometrics* 44, 875-880.

- FILER, D.L. (1988). A database for tree improvement and seed bank management: SISTEM. *Commonwealth Forestry Review* 67 (3) 243–251
- GIBSON, G.L. (1982). Genotype-environment interaction in *Pinus caribaea*. Unit of Tropical Silviculture, Commonwealth Forestry Institute, University of Oxford. 112 pp.
- GIBSON, G.L., BARNES, R.D., BERRINGTON, J. (1983a). Provenance productivity in *Pinus caribaea* and its interaction with environment. *Commonwealth Forestry Review* 62 (2) 93–106.
- GIBSON, G.L., BARNES, R.D., BERRINGTON, J. (1983b). Flowering and its interaction with environment in provenance trials of *Pinus caribaea*. *Commonwealth Forestry Review* 62 (4) 251–263.
- GIBSON, G.L., GRIFFIN, A.R., MATHESON, A.C. [EDITORS] (1990). Breeding tropical trees: Population structure and genetic improvement strategies in clonal and seedling forestry, Pattaya, Thailand, 28 November–3 December 1988. Oxford Forestry Institute, Oxford, UK and Winrock International, Arlington, Virginia, USA. 503 pp.
- GREAVES, A. (1978). Descriptions of seed sources and collections for provenances of *Pinus caribaea*. *Tropical Forestry Papers, Commonwealth Forestry Institute, University of Oxford* No. 12, 100 pp.
- GREAVES, A. (1979). Descriptions of seed sources and collections for provenances of *Pinus oocarpa*. *Tropical Forestry Papers, Commonwealth Forestry Institute, University of Oxford* No. 13, 144 pp.
- GREAVES, A. (1980). Review of the *Pinus caribaea* Morelet and *Pinus oocarpa* Schiede International provenance trial. *C.F.I. Occasional Papers, Commonwealth Forestry Institute, University of Oxford* No. 12, 89 pp.
- GREAVES, A. (1982). *Pinus oocarpa*. Review article. *Forestry Abstracts* 43 (9) 503–531.
- HUGHES, C.E. (1990). Pers. Comm. Oxford Forestry Institute, South Parks Road, Oxford OX1 3RB UK.
- KEMP, R.H. (1973). International provenance research on Central American pines. *Commonwealth Forestry Review* 52 (1) 55–56.
- LAMB, A.F.A. (1973). *Pinus caribaea* Volume 1. Fast-growing Timber Trees of the Lowland Tropics, Commonwealth Forestry Institute, University of Oxford No. 6, 272 pp.
- LIEGEL, L.H., BARNES, R.D., GIBSON, G.L. (1983). Growth and selected assessment traits of *Pinus caribaea* and *P. oocarpa* provenance trials in Puerto Rico. *Silvicultura* 8 (29) 107–111.
- LOOCK, E.E.M. (1950). The pines of Mexico and British Honduras; a report on a reconnaissance of Mexico and British Honduras during 1947. *Bulletin, Department of Forestry, South Africa* No. 35 (2nd edition), 244 pp.
- LUCKHOFF, H.A. (1964). The natural distribution, growth and botanical variation of *Pinus caribaea* and its cultivation in S. Africa. *Annale Universitatis van Stellenbosch* 39 serie A, No. 1.
- MATHESON, A.C., BELL, C., BARNES, R.D. (1989). Breeding systems and genetic structure in some Central American pine populations. *Silvae Genetica* 38, 107–113.
- MCCARTER, P.S., & BIRKS, J.S. (1985). *Pinus patula* ssp. *tecunumanii*: the application of numerical techniques to some problems of its taxonomy. *Commonwealth Forestry Review* 64 (2) 117–132.
- NAMKOONG, G., BARNES, R.D., BURLEY, J. (1980). A philosophy of breeding strategy for tropical forest trees. *Tropical Forestry Papers, Commonwealth Forestry Institute, University of Oxford* No. 16, 67 pp.
- NIKLES, D.G. (1990). Early growth and potential value of *Pinus caribaea* var. *hondurensis* and *P. tecunumanii* and *P. oocarpa* F1 hybrids in Australia. In *Breeding tropical trees: population structure and genetic improvement strategies in clonal and seedling forestry, Pattaya, Thailand, 28 November–3 December 1988*. [edited by Gibson, G.L., Griffin, A.R., Matheson, A.C.] Oxford Forestry Institute and Winrock International. 2 pp.
- NIKLES, D.G., BURLEY, J., BARNES, R.D. [EDITORS] (1978). Progress and problems of genetic improvement of tropical forest trees Vols I and II. Commonwealth Forestry Institute, Oxford, U.K. 1066 pp.
- PLUMPTRE, R.A. & BARNES, R.D. (1982). Economic significance of research and training in the Unit of Tropical Silviculture at the Commonwealth Forestry Institute, Oxford. Commonwealth Forestry Institute, University of Oxford. 8 pp. (mimeographed reprint)
- POTTINGER, A.J., & BARNES, R.D. (1990). The assembly of selected genetic material of tropical pines coordinated by the Oxford Forestry Institute. In *Breeding tropical trees: population structure and genetic improvement strategies in clonal and seedling forestry, Pattaya, Thailand, 28 November–3 December 1988*. [edited by Gibson, G.L., Griffin, A.R., Matheson, A.C.] Oxford Forestry Institute and Winrock International. 418–419.
- POYNTON, R.J. (1979). Tree planting in Southern Africa Vol. 1, The pines. Department of Forestry, South Africa. 576 pp.
- ROBBINS, A.M.J., & HUGHES, C.E. (1983). Provenance regions for *Pinus caribaea* and *Pinus oocarpa* within the Republic of Honduras. *Tropical Forestry Papers, Commonwealth Forestry Institute, University of Oxford* No. 18, 91 pp.
- SNIEZKO, R.A., & MULLIN, L.J. (1987). Taxonomic implications of bush pig damage and basal shoots in *Pinus tecunumanii*. *Commonwealth Forestry Review* 66 (4) 313–316.
- STYLES, B.T. (1985). The identity of *Schwerdtfeger's* Central American pine. *Forest Genetic Resources Information, FAO, Rome* No. 13, 47–51
- STYLES, B.T., & MCCARTER, P.S. (1988). The botany, ecology, distribution and conservation status of *Pinus patula* ssp. *tecunumanii* in the Republic of Honduras. *Ceiba* 29 (1) 3–30.
- STYLES, B.T., STEAD, J.W., ROLF, K.J. (1982). Studies in variation in Central American pines II. Putative hybridization between *P. caribaea* var. *hondurensis* and *P. oocarpa*. *Turrialba* 32 (3) 229–242.
- SZMIDT, A.E. (1988). Genetic relationships among *Pinus* species based on chloroplast DNA polymorphism. In *Molecular Genetics of Forest Trees*, [edited by Hallgren, J.-E.] Swedish University of Agricultural Sciences, Umea. 33–47.
- WRIGHT, J.A., GIBSON, G.L., BARNES, R.D. (1986). Provenance variation in stem volume and wood density of *Pinus caribaea*, *P. oocarpa* and *P. patula* ssp. *tecunumanii* in Zambia. *Commonwealth Forestry Review* 65 (1) 33–40.
- WRIGHT, J.A., GIBSON, G.L., BARNES, R.D. (1987). Provenance variation in stem volume and wood density of *Pinus oocarpa* and *P. patula* ssp. *tecunumanii* growing at two elevations in South Africa. *South African Forestry Journal* 143, 46–48.
- YATES, F. (1933). The principles of orthogonality and conformity in replicated experiments. *Journal of Agricultural Science* 23, 108–145.

