this species and to identify the best provenances under New Zealand conditions.

Natural Distribution and Taxonomy of Pinus Nigra

European black pine (*Pinus nigra* Arnold) is a southern European species extending from Spain in the west to central Turkey in the east. Between these extremes it exhibits a discontinuous range consisting of several major separated areas, and many isolated occurrences. It is generally regarded as a relict species of the Tertiary period, once occupying a wider area than it does now. Details of its distribution, ecology, and various forms have been described by Arbez and Millier (1971), Debazac (1963; 1964; 1971), Lee (1968), Röhrig (1957; 1966), and Sexton (1947). The natural distribution based on Critchfield and Little (1966) is shown in *Fig. 1.*

Partly as a result of its wide but discontinuous range, the study of the taxonomy of *P. nigra* has proved laborious and controversial. On the basis of an exhaustive description, Röhrig (1957) considered all forms to belong to the one species. The same conclusion was reached by Vidaković (1974) in his recent review of the genetics of *P. nigra.* In their *Flora Europaea,* Tutin *et al.* (1964) regarded all forms of *P. nigra* as belonging to one species and advanced a nomenclature for subdivision into various subspecies which we have adopted to classify the provenances in the New Zealand experiments.

Pinus nigra subspecies *salzmannii* (Dunal) Franco. — Spain, south-west France (Cévennes) and North Africa. The natural area occupied by *salzmannii* in Spain has been estimated to be 400 000 ha (Debazac, 1971).

Pinus nigra subspecies *laricio* (Poiret) Maire. — Corsica, Sicily, and southern Italy (Calabria). The Corsican provenance, covering a natural area of about 22 000 ha (Debazac, 1971), has a high reputation and has been widely planted as an exotic forest tree in Great Britain, Europe, and New Zealand. It is generally known as Corsican pine. Calabrian pine occupies an area of roughly 50 000 ha in southern Italy and Sicily.

Pinus nigra subspecies *nigra* — Austria, north-eastern and central Italy, and Yugoslavia. The Austrian provenance from near Vienna is well known as an exotic forest tree. This subspecies occupies an area of about 800 000 ha, the largest tracts occurring in Yugoslavia.

Pinus nigra subspecies *pallasiana* (Lambert) Holmboe. — Greece, Bulgaria, Romania, Turkey, Cyprus, and the Crimean Peninsula (U.S.S.R.). This subspecies is said to occupy 1 million ha in Turkey alone but is little-known as an exotic (Debazac, 1971).

Description of the New Zealand Provenance Trials

The New Zealand provenance trials compare 43 separate seedlots of which 34 were collected from native stands, 5 from exotic European stands, and 4 from exotic New Zealand stands. They were established between 1956 and 1958 from two nursery sowings made in 1954 and 1955. The main trial was originally planted at four sites in the North Island and four in the South Island, but only those at Karioi, Ngaumu, Golden Downs, Hanmer, Naseby, and Berwick Forests are discussed here. At these sites, fully randomised plots were of 100 or 144 trees at 2.4 × 2.4-m spacing, the number of plots per provenance per site varying from one to three. The trials were neither pruned nor thinned. A small subsidiary trial was established at Whakarewarewa (Whaka) Forest near Rotorua in the North Island in 1957.

Particulars of seed origins are summarised in *Table 1,* and descriptions of trial sites are given in *Table 2.*

The approximate origins of the native and exotic European seedlots are shown in *Fig. 2.* The number of parent trees represented in each seedlot is unknown except that the four New Zealand seedlots were all commercial col-

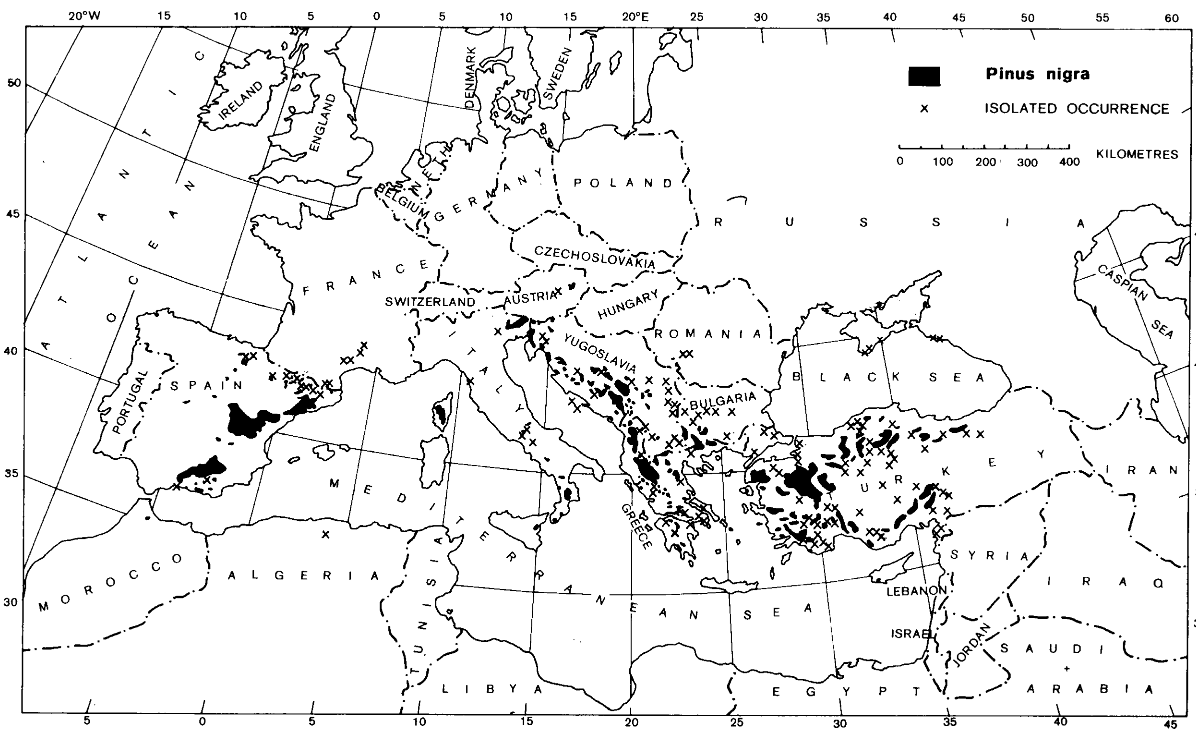

Fig. 1. — Natural distribution of *Pinus nigra.*

lections from numerous trees. Locations of the trial sites and of the New Zealand seed origins are shown in *Fig. 3*.

The trials were first assessed at age 8—9 years from sowing (MILLER and THULIN, 1967). The second assessment was carried out in March 1974 to update the earlier results. Trees were then 19 and 20 years old and mature enough to furnish a conclusive picture of the merit in New Zealand of the four major subspecies.

Method

Measurements

Thirty randomly selected trees from each provenance at each site were measured in March 1974 as follows:

1. *Height* (dm)
2. *Diameter at breast height — 1.4 m* (mm)
3. *Stem straightness* (1—9) [1 = very crooked, 9 = perfectly straight]
4. *Forking* (0 or 1) [0 = single stem, 1 = forked]
5. *Total stem volume* (dm^3) was estimated from height and diameter at 1.4 m from $V = 0.4 \left(\frac{d}{100}\right)^2 h$. This assumes that the stems have the form of a paraboloid.

The thirty-tree sample was made up of one sub-sample of 30, two sub-samples of 15 (or one of 20 and one of 10), or three sub-samples of 10 trees, depending on whether there were 1, 2, or 3 plots of the particular provenance in question. Badly suppressed trees were excluded.

Assessment of infection by Dothistroma pini

P. nigra subsp. *laricio* in commercial plantations in the Rotorua region in New Zealand is highly susceptible to *Dothistroma* needle blight, while *P. nigra* subsp. *nigra* is generally only mildly susceptible (GILMOUR, 1967).

The subsidiary provenance trial at Whaka Forest near Rotorua, comprising 32 of the 43 seedlots planted in unreplicated row plots, became infected with *Dothistroma* about 1966 and subsequently suffered repeated annual attacks. A visual assessment was made in December 1974 of the percentage of current and total foliage infected with *Dothistroma*. Seedlot means were estimated from 6—19 individual tree scores, and subspecies means calculated from the seedlot means.

Other observations

A record was made of any obvious peculiarities of the provenances such as branching habit, foliage characteristics, frost damage, and damage by the introduced opossum, *Trichosurus vulpecula* KERR.

Analysis

Estimation of provenance and location means: Provenance means at each location were estimated from the arithmetic mean of the 30 trees measured. Means of 33 provenances over six locations were estimated from the arithmetic mean of the 180 trees measured. Provenanecs 266, 509, and 605 were planted at only five, four, and five of the six locations respectively. Least squares estimates were made of the means at the "missing" locations (HASEMAN and GAYLOR, 1973). In all, provenance means over six locations were obtained for 36 of the 43 provenances. The remaining 7 provenances were planted at three or fewer of the six locations, and no estimate of their mean performance was made. Location means were based on the arithmetic means of 36 provenances. No adjustments to provenance or location means were made to allow for 1-year differences in age among certain provenance-location subclasses.

Estimation of variances and covariances: Untransformed individual tree data of 33 provenances at six locations were analysed following the random effects model:

$$y^{P}_{ijkm} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \nu_{k(ij)} + e_{ijkm}$$

where y^{P}_{ijkm} = the measurement of the p^{th} trait on the

Table 1. - *Pinus nigra* provenances

Subspecies	Seedlot number	Provenance	Latitude	Longitude	Altitude (m)
Salzmannii	140	Spain : Cazorla	37°58'N	2°51'W	1100
	264	Spain : Arenas de San Pedro	40°12'N	5°06'W	500
	265	Spain : Navalacruz	40°26'N	4°53'W	1300
	266	Spain : Casarejos	41°46'N	3°05'W	1100
	267	Spain : Forest of "Llera"	42°01'N	1°29'E	830
	268	Spain : El Codorzo y los Llecos	39°48'N	2°05'E	1050
	269	Spain : Plá de Hedra, Comuns	40°55'N	0°22'E	850
	222	France : Cévennes	44°00'N	3°30'E	?
	557	France : St-Guilhem-le-Désert	43°45'N	3°35'E	500
	558	France : Province d'Olette	42°34'N	2°16'E	950
Laricio	223	Corsica : ?	42°00'N	9°00'E	1130
	273	Corsica : Forest of Marghese, Porto Vecchio	41°30'N	9°10'E	1200
	472	Corsica : Vivario and Vezzani	42°10'N	9°15'E	1200
	555	Corsica : Vivario and Vezzani	42°10'N	9°15'E	1200
	231	Sicily : Mt Etna	39°18'N	16°25'E	1200
	232	Sicily : Mt Etna	37°45'N	14°55'E	1500
	230	Italy : La Sila, Calabria	39°18'N	16°25'E	1100
	310	Italy : Reggio di Calabria	38°00'N	15°50'E	?
	* 289	Denmark : Jaegerspris Forest	55°45'N	12°00'E	?
	* 360	England : Hampshire	51°05'N	00°50'W	?
	* 361	England : Hampshire	51°05'N	00°50'W	?
	* 476	England : Hampshire	51°05'N	00°50'W	?
	* 492	New Zealand : Dusky Forest	45°50'S	169°10'E	260
	* 509	New Zealand : Dumgree Forest	41°40'S	174°00'E	100
	* 519	New Zealand : Whaka Forest	38°10'S	176°15'E	300
	* 605	New Zealand : Tasman West	41°13'S	173°00'E	100
Nigra	229	Italy : Villetta Barrea	41°50'N	13°53'E	1200
	350	Italy : Tarvisio	46°25'N	13°30'E	625
	362	Yugoslavia : S.W. Serbia	43°50'N	19°20'E	900
	365	Yugoslavia : Višegrad	43°55'N	19°14'E	900
	366	Yugoslavia : Teslic	44°27'N	17°50'E	750
	398	Yugoslavia : Bosnia	?	?	?
	399	Austria : Lower Austria	?	?	?
	556	Austria : Wiener Neustadt	47°49'N	16°16'E	?
	* 210	France : Ardennes	49°30'N	4°30'E	200
Pallasiana	490	Yugoslavia : Strumica, Macedonia	41°26'N	22°39'E	500
	491	Yugoslavia : Marihovo Mts, Bitola	41°02'N	21°21'E	1400
	292	Cyprus : Troödos, Damaskinari	35°00'N	33°00'E	1400
	548	Greece : Taÿgetos Óros Mts	37°00'N	22°10'E	1100
	233	Turkey : Tokat	40°15'N	36°30'E	475
	234	Turkey : Burdur	37°40'N	30°20'E	1350
	235	Turkey : Dursunbey	39°19'N	28°30'E	900
	236	Turkey : Beyşehir	37°40'N	31°40'E	?

* Exotic provenances

Table 2. - Description of sites

Site	Altitude (m)	Mean Annual Rainfall[1] (mm)	Mean Max. Temp. of Hottest Month (°C)	Mean Min. Temp. of Coldest Month (°C)	Soil: Soil type[2]	Soil: Parent material
Whaka	300	1552	23.2	2.2	Loamy sand	Rhyolitic ash
Karioi	1000	1143	22.7	0.0	Silty loam	Andesitic ash
Ngaumu	250	1091	23.6	0.8	Sandy loam	Sandstone
Golden Downs	450	1305	23.1	-1.6	Stony loam	Greywacke gravel
Hanmer	450	1038	23.8	-2.3	Stony silt loam	Greywacke
Naseby	800	590	21.8	-3.6	Silt loam	Greywacke gravel
Berwick	50	741	21.2	-0.5	Silt loam	Schist loess and greywacke

1) Climatic data are means over period 1965-73. Figures from New Zealand Meteorological Service

2) All soils are well drained

m^{th} tree in the k^{th} plot of the i^{th} provenance at the j^{th} location;

μ = constant general mean;

a_i = effect of the i^{th} provenance ($i = 1,2 \ldots, a$; $a = 33$ out of ∞);

β_j = effect of the j^{th} location ($j = 1,2 \ldots, b$; $b = 6$ out of ∞);

$(\alpha\beta)_{ij}$ = effect of the interaction between the i^{th} provenance and j^{th} location;

$\nu_{k(ij)}$ = effect of the k^{th} plot in the i-j^{th} provenance-location cell ($k = 1,2, \ldots, c_{ij}$; c_{ij} = 1,2, or 3 out of ∞);

e_{ijkm} = effect of the m^{th} tree in the k^{th} plot of the i-j^{th} cell ($m = 1,2, \ldots, n_{ijk}$; n_{ijk} = 10, 15, 20, or 30 out of ∞).

Estimates of variance and covariance components corresponding to each term in the model were obtained from the analysis outlined in *Table 3*. The estimation procedure was adapted from a method proposed by HARTWELL (1971) for unbalanced designs with two levels of nesting.

Selection index for provenance selection: Provenances were ranked on their average performance over all six locations, as measured by a selection index incorporating provenance and phenotypic variances and covariances, and economic weights. The index was of the form:

$$I = b_1P_1 + b_2P_2 + b_3P_3$$

where trait 1 = volume per tree
trait 2 = straightness
trait 3 = forking percent

and the b's were solutions to the equations

$$P\underline{b} = AS^{-1}\underline{a}$$

where P is the phenotypic variance-covariance matrix,
A is the provenance variance-covariance matrix,
S is a diagonal matrix of phenotypic standard deviations,
and $\underline{a}$ is a vector of economic weights.

Relative economic weights assumed were \$5/standard deviation (S.D.), or \$0.27/dm^3 for volume, \$3/S.D. (\$3.09/point) for straightness, and —\$2/S.D. (—\$1.70/10%) for forking. The index provides an estimate of the economic value of each provenance.

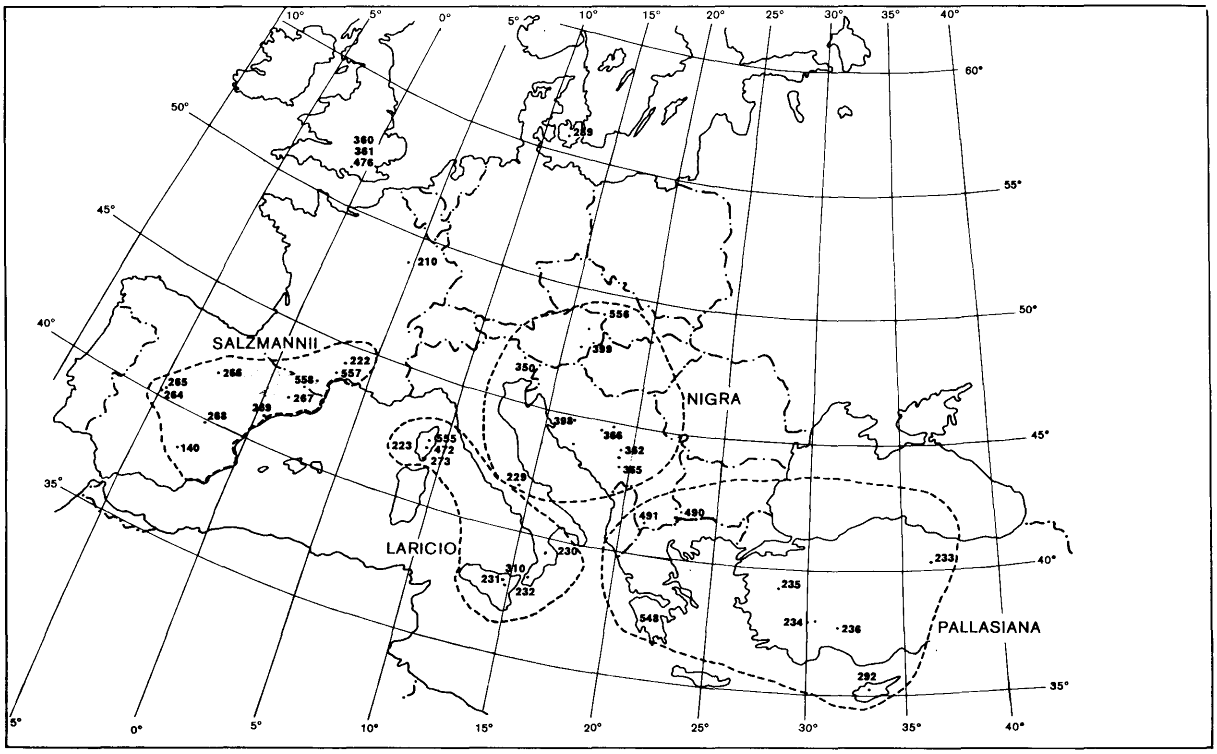

Fig. 2. — Origins of *Pinus nigra* seedlots.

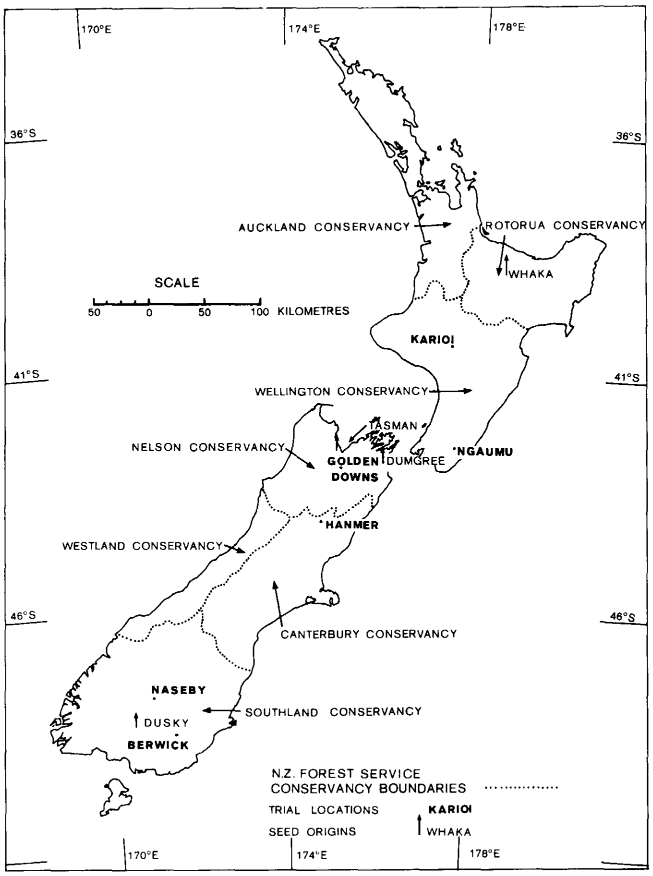

Fig. 3. — Locations of *Pinus nigra* provenance trials and origins of four exotic seedlots collected in New Zealand.

Table 3. – Analysis of variance table for estimation of variance components

Source of variation	df	SS 1)	MS	E(MS) 2)
Provenances	a - 1	$T_A - T_\mu$	M_1	$\sigma^2_w + k_1\sigma^2_p + c\sigma^2_{ge} + cb\sigma^2_g$
Locations	b - 1	$T_B - T_\mu$	M_2	$\sigma^2_w + k_1\sigma^2_p + c\sigma^2_{ge} + ca\sigma^2_e$
Prov. x loc.	(a-1)(b-1)	$T_{AB} - T_A - T_B + T_\mu$	M_3	$\sigma^2_w + k_1\sigma^2_p + c\sigma^2_{ge}$
Plots:cells	p - ab	$T_{ABC} - T_{AB}$	M_4	$\sigma^2_w + k_2\sigma^2_p$
Trees:plots	N - p	$T_O - T_{ABC}$	M_5	σ^2_w

1) $T_A = 1/cb \sum_i Yi...^2$

$T_B = 1/ca \sum_j Y.j..^2$

$T_{AB} = 1/c \sum_i \sum_j Yij..^2$

$T_{ABC} = \sum_i \sum_j \sum_k \frac{Yijk.^2}{nijk}$

$T_O = \sum_i \sum_j \sum_k \sum_m Yijkm^2$

$T_\mu = Y^2..../N$

2) $k_1 = \frac{\sum_i \sum_j \sum_k n_{ijk}^2}{N} = 23.653$

$k_2 = \frac{(N - \sum_i \sum_j \sum_k \frac{n_{ijk}^2}{c})}{p - ab} = 10.833$

a = number of provenances = 33

b = number of locations = 6

p = total number of plots = 314

c = number of observations per provenance-location cell = 30

n_{ijk} = number of observations in the k^{th} plot of the ij^{th} cell

N = total number of observations = 5940

Results

Variation

There were important differences among provenances in all characters measured, with height showing the most significant provenance variation *(Table 4)*. The variance among locations was very large, with mean volume per tree varying from 30.7 dm³ at Naseby to 133.8 dm³ at Golden Downs.

Provenance x site variance was apparent in all traits *(Table 4)*. However, since only one plot of each provenance occurred at two of the sites, what appears to be provenance x site interaction in *Table 4* could in many cases merely reflect local environmental variation rather than genuine instability of performance. No important changes in rank occurred at the subspecies level. For example, the New Zealand provenances were the tallest and straightest at all six sites *(Table 5)*. The high overall provenance repeatabilities enabled New Zealand-wide ranking of provenances to be made with considerable confidence.

Table 4. – Variance component estimates and repeatabilities of provenance means

Character / Component	Volume (dm^3)	Diameter (mm)	Height (dm)	Straightness (1-9)	Forking (%)
Provenance	297.54 ± 81.72	320.63 ± 86.88	81.50 ± 21.08	0.842 ± 0.228	101.99 ± 32.74
Location	1450.42 ± 779.06	711.85 ± 384.11	298.58 ± 160.12	0.486 ± 0.269	293.65 ± 160.09
Prov. x loc.	117.84 ± 35.86	160.45 ± 31.76	32.25 ± 3.59	0.407 ± 0.078	46.57 ± 32.89
Plots : cells	67.22 ± 31.34	79.45 ± 25.15	- 1)	0.228 ± 0.054	185.73 ± 31.63
Within plot	1879.83 ± 35.44	1232.09 ± 23.23	384.14 ± 7.24	1.998 ± 0.038	619.80 ± 11.68
Phenotypic 2) (prov. mean)	336.45 ± 57.70	357.81 ± 61.36	86.87 ± 14.90	0.940 ± 0.161	134.16 ± 23.01
Repeatability 3) of prov. means	0.88	0.90	0.94	0.90	0.76
F-test for prov. effects	8.64**	9.62**	16.16**	9.62**	4.17**
F-test for 4) prov. x loc. effects	2.02**	2.15**	2.54**	2.38**	1.03 ns

1) Negative estimate

2) Phenotypic variance of provenance means ($\hat{\sigma}^2_{Phen}$) = Mean Square Prov/180

3) $\hat{R} = \hat{\sigma}^2_{Prov}/\hat{\sigma}^2_{Phen}$

4) Based on SATTERTHWAITE's (1946) approximation.

Table 5. - Subspecies means for height and straightness at each site

Height (dm)

Site / Subspecies	Karioi	Ngaumu	Golden Downs	Hanmer	Naseby	Berwick	New Zealand
Laricio (N.Z.)	60	85	108	84	63	91	82
Laricio (other)	51	72	97	71	49	82	70
Salzmannii	50	68	88	69	50	73	66
Nigra	39	60	83	64	44	70	60
Pallasiana	32	44	82	59	37	69	54
Mean	46	64	91	66	47	76	65

Straightness (1-9)

Site / Subspecies	Karioi	Ngaumu	Golden Downs	Hanmer	Naseby	Berwick	New Zealand
Laricio (N.Z.)	7.5	7.6	6.3	7.7	6.2	5.7	6.9
Laricio (other)	6.4	7.3	5.4	6.9	5.9	5.1	6.2
Salzmannii	3.6	5.3	4.2	5.3	4.0	3.6	4.3
Nigra	4.5	6.3	4.7	6.2	5.0	4.4	5.2
Pallasiana	3.4	4.5	4.8	6.2	4.7	4.6	4.7
Mean	4.9	6.1	5.0	6.3	5.0	4.6	5.3

Characteristics of subspecies

Observations and descriptions made during the assessment disclosed that the Corsican and exotic provenances of *laricio* were not attacked by opossums. The usual form of damage by this marsupial is ringbarking and killing of leaders and branches of young trees, often with permanent disruption of normal stem development at that point. Virtually all the provenances of *salzmannii*, *nigra*, and *pallasiana* were severely damaged by oppossums. At Karioi and Ngaumu, many provenances of these subspecies were reduced to multistemmed bushes. Only minor opossum damage was recorded on Sicilian *laricio*, but the Calabrian provenances suffered some damage.

The Corsican and exotic *laricio* provenances were further characterised by fine horizontal branches, soft foliage, and an unusually uniform appearance which vividly impressed all observers. *Laricio* provenances from Sicily and Calabria were coarser and more variable than the Corsican provenances. The Spanish and French provenances of *salzmannii* were often of large diameter, but their branching was extremely coarse, giving them bushy broad crowns. Provenances of *nigra* and *pallasiana* had very harsh foliage, sharp-pointed buds, atrocious stem and branch quality, and were generally the slowest growing of all.

Some frost injury occurred at the Karioi site on the slopes of Mt. Ruapehu. Native and exotic Corsican provenances suffered negligible damage, but there was high mortality in some provenances from Sicily, Calabria, Yugoslavia, Greece, and Cyprus.

Selection

Provenance rankings based on the selection index
$I = (0.275 \times \text{volume}) + (2.117 \times \text{straightness}) - (0.250 \times \text{forking})$ are shown in *Tables 6 and 7*. The result is clear-cut: the best provenances of *P. nigra* were of subspecies *laricio*, and the local New Zealand sources were more vigorous and straighter than the native and European exotic *laricio* provenances. The New Zealand provenances ranked high in all traits taken separately as well as in the three-trait index, leaving no doubt of their superiority. There was, however, a higher incidence of forking in the New Zealand seedlots than in the *laricio* seedlots from Corsica and Sicily.

Site effects

The site means are shown in *Table 8*. Growth was best at Golden Downs, followed by Berwick, Ngaumu and Hanmer, Karioi, and Naseby. Form was best at Hanmer where a very low average incidence of forking was recorded. The high incidence of forking and comparatively poor form of many of the provenances at Karioi, Berwick, and Ngaumu was partly attributable to opossum damage.

Dothistroma resistance

Subspecies means from the subsidiary provenance trial at Whaka Forest are shown in *Table 9*.

Subspecies *nigra* provenances from Austria and Yugoslavia were highly resistant to *Dothistroma*. Seedlot 350 from northern Italy, also classified as *nigra*, was markedly susceptible and stood apart from the other *nigra* provenances. Provenances of subspecies *pallasiana* varied considerably in susceptibility: the two Yugoslavian seedlots, 490 and 491, were highly resistant; the single Greek seedlot, 548, was highly susceptible; Turkish seedlots generally showed good resistance. The *salzmannii* seedlots also varied in their susceptibility, with the French provenances showing considerably greater susceptibility than the Spanish ones. The most susceptible subspecies was *laricio*, with the New Zealand seedlots suffering particularly severe attack and defoliation.

Discussion

The preliminary conclusion from these provenance trials after 9 years had been that the Spanish provenances of subspecies *salzmannii* were the most vigorous (Miller and Thulin, 1967). After 20 years, provenances of subspecies *laricio* were generally the fastest growing on all sites.

A local race of Corsican pine, more vigorous and straighter than the native races, has apparently arisen in one or two generations. The story of Corsican pine in New Zealand is a good example of the often-observed superiority of local exotic races (Burdon and Bannister, 1973; de Vecchi Pellati, 1969). Why New Zealand Corsican pine should be faster-growing in New Zealand than the native or European exotic races can only be guessed at, but the most likely reasons may be:

a) Response to natural and silvicultural selection (e.g., thinning and seed collection from the best trees) after one or more generations in New Zealand environments;

b) A higher level of outcrossing in plantations than typically occurs in natural stands, which would be expected to give a release from any inbreeding depression;

c) Original imports of seed from Corsica to New Zealand were of faster growing provenances than those of the seed samples collected in 1953—54 and used in the provenance trials as representative of the native Corsican pine. Alternatively, it is possible that *P. nigra* in Corsica suffered genetic deterioration during the period between the earliest seed imports to New Zealand (*circa* 1900) and the seed collections made in 1953—54. Dysgenic effects in the

Table 6. - Provenances ranked by a selection index

Provenance	Subspecies	Origin	Index ($)	Volume (dm^3)	Diameter (mm)	Height (dm)	Straightness (1-9)	Forks (%)
509	laricio	N.Z. (Dumgree)	38.76	108.9	170.3	84.6	7.1	25
605	"	N.Z. (Nelson)	37.02	101.1	165.8	82.0	6.7	20
519	"	N.Z. (Whaka)	35.99	107.1	168.9	82.1	6.5	29
492	"	N.Z. (Dusky)	34.83	91.0	159.3	77.9	7.1	21
360	"	England	33.18	95.7	158.4	79.2	6.3	26
223	"	Corsica	32.74	82.7	159.5	72.2	6.6	16
273	"	Corsica	32.21	75.3	152.3	71.0	6.6	10
232	"	Sicily	31.56	80.0	157.7	63.3	5.8	11
361	"	England	30.15	77.2	144.0	74.0	6.8	22
230	"	Italy (Calabria)	29.58	87.1	162.6	70.1	5.6	25
555	"	Corsica	28.54	70.8	141.0	72.4	6.4	18
231	"	Sicily	28.03	68.1	148.6	63.7	5.8	12
558	salzmannii	France	27.78	74.0	147.8	72.9	6.1	22
310	laricio	Italy (Calabria)	27.38	84.0	164.2	66.8	5.2	27
472	"	Corsica	26.81	67.4	142.6	70.1	6.5	22
269	salzmannii	Spain	24.48	91.0	173.5	69.0	4.1	37
268	"	Spain	24.16	76.5	158.7	65.9	4.3	24
362	nigra	Yugoslavia	23.31	69.0	147.2	66.5	5.7	31
140	salzmannii	Spain	21.57	69.6	158.7	61.8	4.8	31
222	"	France	21.48	68.3	152.5	64.6	4.1	24
235	pallasiana	Turkey	20.23	65.8	147.7	60.8	4.9	33
264	salzmannii	Spain	19.95	76.4	164.3	65.5	4.1	39
266	"	Spain	19.86	79.0	165.4	67.8	3.6	38
210	nigra	France	19.41	66.4	147.3	64.3	5.5	42
229	"	Italy	19.22	55.7	142.2	59.7	5.5	31
267	salzmannii	Spain	19.19	82.0	165.1	69.5	3.6	44
491	pallasiana	Yugoslavia	17.17	46.3	124.0	55.4	5.4	28
234	"	Turkey	17.06	57.8	137.6	58.3	4.8	36
557	salzmannii	France	16.80	56.0	142.0	60.7	4.2	30
236	pallasiana	Turkey	16.10	51.0	125.1	52.2	4.4	29
548	"	Greece	15.48	55.2	135.1	57.6	5.1	42
233	"	Turkey	14.97	55.3	132.0	58.9	3.9	34
556	nigra	Austria	14.21	43.5	125.5	55.6	4.6	30
292	pallasiana	Cyprus	10.10	20.7	76.8	35.4	4.8	23
490	"	Yugoslavia	9.58	37.2	116.7	51.2	4.3	39
350	nigra	Italy	3.96	42.8	127.0	53.6	4.7	71

Table 7. - Subspecies means over six sites

Subspecies	Number of provenances	Index ($)	Volume (dm^3)	Diameter (mm)	Height (dm)	Straightness (1-9)	Forks (%)
Laricio (N.Z.)	4	37	102	166	82	6.9	24
Laricio (other)	10	30	79	153	70	6.2	19
Salzmannii	9	22	75	159	66	4.3	32
Nigra	5	16	55	138	60	5.2	41
Pallasiana	8	15	49	124	54	4.7	33

native stands due to heavy selective exploitation of the best trees would seem unlikely in view of the management history of the stands in Corsica (Sexton, 1947; Woolsey, 1917).

The best New Zealand seedlot in the experiment, No. 509, was one of numerous commercial seedlots collected from the Dumgree plantation in Marlborough. The original Dumgree stands were planted about 1905—07, but no records exist of original seed sources. Whether the immediate ancestors of 509 in Dumgree were from seed collected in Corsica or from plantations in England or Europe, or even in New Zealand, is not known. During the period 1927—51, 1422 kg of seed was collected from Dumgree and used widely throughout New Zealand. Thus, from the provenance point of view, many of the younger *P. nigra* stands in the country are near optimum.

The Corsican type of subspecies *laricio* has long been a popular provenance for forestry in Great Britain, New

Table 8. - Site means

Site	Volume (dm^3)	Height (dm)	Diameter (mm)	Straightness (1-9)	Forks (%)
Golden Downs	134	91	186	5.0	34
Berwick	95	76	171	4.6	31
Ngaumu	62	64	142	6.1	36
Hanmer	60	66	139	6.3	8
Karioi	41	46	132	4.9	54
Naseby	31	47	113	5.0	11

Table 9. - Infection of Pinus nigra subspecies by Dothistroma needle blight at Whaka Forest, Rotorua

Subspecies	No. of provenances	Percentage foliage infected	
		Current	Total
Laricio (N.Z.)	4	57.4	71.9
Laricio (other)	7	37.0	49.4
Salzmannii	7	23.7	34.2
Pallasiana	7	13.4	20.1
Nigra	6	9.3	16.1

Zealand (Weston, 1957), and Belgium (Gathy, 1961). However, in the United States (Lee, 1968; Wright and Bull, 1962) and in West Germany (Röhrig, 1966) Corsican pine is reported to be easily injured by severe winter cold. The hardiest subspecies there are *nigra* and *pallasiana*. By long-standing reputation in New Zealand Corsican pine is regarded as a relatively hardy tree and has customarily been sited beyond the margins set in this respect for *Pinus radiata*.

At the Ngaumu and Karioi trials opossums damaged numerous trees of *nigra, pallasiana,* and *salzmannii* by eating the bark off the upper part of the main stem and longer side branches. Some opossum damage was observed on the Calabrian provenances of *laricio* but the Corsican provenances, including the exotics, were not damaged. Possible reasons for this variation in opossum resistance have not been investigated, but could well be related to chemical differences such as those detected for monoterpene content by Arbez *et al.* (1974), who showed that Corsican *laricio* was notable for its high limonene content and presence of Δ_3-carene. No other provenances contained this latter monoterpene.

Wood quality in New Zealand *P. nigra* has recently been surveyed by Cown (1974), and shown to be generally excellent. Provenance variation in wood density seems to be insignificant, judging by the results of a small study made in the subsidiary trial in Whaka Forest. In wood density the *laricio* provenances were comparable with the other subspecies and had a mean basic density of 402 kg/m^3 at age 17 years.

The otherwise superior native and exotic Corsican provenances of *laricio* suffered the greatest attack and defoliation from *Dothistroma pini* needle blight. This has long been apparent in the Kaingaroa and Whaka State Forests near Rotorua where 30- to 40-year-old stands of "Corsican" have suffered badly in comparison with "austriaca". As in New Zealand, Yugoslavian and Austrian provenances of *nigra* in North American plantations have proved to be the most resistant to *Dothistroma* (Peterson and Read, 1971). Since *laricio* is the only subspecies of *P. nigra* which may still have a place in New Zealand forestry, it must be accepted that the risk from *Dothistroma* in most areas of New Zealand except Canterbury and Southland (where *Dothistroma* is still absent) will be prohibitive.

Application of Results

Corsican pine is not now planted on a significant scale anywhere in New Zealand because of its susceptibility to *Dothistroma pini* needle blight and its inability to match the growth rates of *Pinus radiata*. Nevertheless, there is a lingering interest in Corsican pine for higher altitude plantations, and it is still widely regarded as the best exotic conifer for transmission poles. A small demand for seed may therefore continue.

Seed stands were formed in the 1950s by heavily thinning old Corsican pine stands in various parts of New Zealand. Very little seed has ever been collected from them because the trees were too big to climb and the demand for seed was small.

An immediate outcome of the provenance trial results has been to reserve a young stand of the best available local provenance (corresponding to No. 509) in a *Dothistroma*-free locality, and develop it as a national seed stand. This 16-year-old stand is 14 ha in area and is located in Rankleburn Forest in Southland.

Beyond provenance selection, no genetics and tree breeding work has been undertaken on *P. nigra* in New Zealand; none is contemplated because of the very minor future role this species is expected to play in New Zealand forestry.

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Summary

Provenance trials of *Pinus nigra* subspecies *salzmannii, laricio, nigra,* and *pallasiana* on six sites in New Zealand were assessed when 20 years old.

Native and exotic Corsican pine provenances of subspecies *laricio* were clearly the best in almost every respect. They had consistently excellent stem form and branching habit, they gave the greatest volume production, they were hardy against unseasonable frosts, and were not attacked by opossums. Unfortunately, *laricio* proved in New Zealand to be the most susceptible subspecies of *P. nigra* to *Dothistroma pini* needle blight.

Some provenances of subspecies *salzmannii* from Spain and France had good diameter growth but merchantable volumes were low because of stem malformation, extremely coarse branching, and comparatively short stems. The slowest growing provenances were of subspecies *nigra* (e.g.,

from Austria) and *pallasiana* (e.g., from Turkey). Subspecies *nigra* was highly resistant to *Dothistroma.* None of the subspecies, except *laricio*, are considered to have commercial potential in New Zealand.

Laricio provenances from New Zealand exotic stands were faster growing than the native Corsican pine. The superior vigour of New Zealand seedlots is attributed to natural and silvicultural selection in one or two generations in New Zealand environments, and may also reflect a higher degree of outcrossing in plantations than typically occurs in native stands.

Though even the best provenances are too slow-growing in New Zealand to offer a viable alternative to the staple radiata pine, Corsican pine might still be a useful tree for harsher sites in the South Island of New Zealand where risk from *Dothistroma* is low. Seed is available from old plantations being clearfelled, and an excellent young stand in Southland has been heavily thinned as a potential seed stand. Since *P. nigra* is expected in future to play only a minor role in New Zealand forestry, there are no plans to further improve the species by way of plus tree selection and seed orchards.

Key words: Pinus nigra Arnold, subspecies, provenance, *Dothistroma pini*, selection index.

Zusammenfassung

An 6 Orten in Neuseeland angelegte Provenienzversuche mit den *Pinus nigra*-Subspecies *salzmannii, laricio, nigra* und *pallasiana* wurden im Alter 20 untersucht. Hierbei erwiesen sich Herkünfte der Subspecies *laricio* sowohl aus Sekundärbeständen in Neuseeland sowie aus autochthonen Beständen auf Korsika als am besten geeignet, was die Stammform, den Zweighabitus und den Holzzuwachs betrifft. Außerdem waren die *laricio*-Provenienzen resistent gegen Fröste außerhalb der Winterruhe; zugleich waren auch keine Fraßschäden durch Opossums zu verzeichnen. Jedoch gerade bei diesen Provenienzen war der Befall durch *Dothistroma pini* am stärksten. Einige Provenienzen der Subspecies *salzmannii* aus Spanien und Frankreich hatten einen guten Durchmesserzuwachs, aber schlecht geformte Stämme. Zu den schwachwüchsigsten Provenienzen gehörten solche der Subspecies *nigra*, insbesondere aus Österreich und der Subspecies *pallasiana*, insbesondere aus der Türkei, wobei soche Provenienzen andererseits gegen *Dothistroma pini* weitgehend resistent waren.

Ein wirtschaftlicher Wert für den Anbau der *Pinus nigra* in Neuseeland ist ausschließlich der Subspecies *laricio* zuzumessen, wobei Nachkommenschaften aus Sekundärbeständen in Neuseeland besser zu beurteilen sind als solche aus Beständen auf Korsika, was wiederum auf die Selektion durch waldbauliche Maßnahmen in den entsprechenden neuseeländischen Mutterbeständen zurückgeführt wird. Insgesamt gesehen wächst *Pinus nigra laricio*, insbesondere gegenüber *Pinus radiata* zu langsam, um wirtschaftlich eine Alternative darzustellen. Für den Anbau kommen evtl. Standorte in rauhen Lagen auf der Südinsel Neuseelands in Frage, wo zugleich das Risiko eines Befalls durch *Dothistroma pini* gering ist.

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