# Variation in Growth and Quality Characters in Pinus pinaster Provenances grown at seven Sites in Greece

By D. I. Matziris[1])

(Received 10th December 1981)


## Summary

Variation in the performance of four provenances of Maritime pine (*Pinus pinaster* Ait.) have been observed in 9-year-old provenance tests grown at seven locations in Greece. The differences in growth among provenances were statistically significant and large enough to warrant selection of the fastest growing provenance for planting.

Portuguese and Landes provenances which belong to the atlantic race had similar growth and were better than Cevennes and Corsican provenances. The Corsican provenance was the slowest in growth but the best in stem straightness and crown form. The variation observed in proportion of fruiting trees were much more profound. In the French provenances Landes and Cevennes, 60 and 62 percent of the trees were fruiting; in the Corsican and Portuguese provenances the proportions were 22 and 33 percent respectively.

The differences among locations were also impressive. The best growth was achieved at Varetada where the mean annual increment over the nine-year period was 0.64 m; the worst was in the sandy soil planting of Kounoupeli (0.36 m per year). The performance of the provenance were consistent at all locations and no significant provenance × location interaction was detected thus indicating genetic stability of the provenances tested.


*Key words: Pinus pinaster, Pinus maritima,* maritime pine, provenance, variation, interaction effect.


## Zusammenfassung

In neun Jahre alten Provenienzversuchen mit vier Herkünften von *Pinus pinaster* Ait. auf 7 Standorten in Griechenland wurde die phänotypische Variation untersucht. Die Unterschiede im Höhenwachstum waren statistisch signifikant und groß genug, um eine Selektion auf die schnellwüchsigsten Provenienzen hin durchführen zu können. Portugiesische und griechische Herkünfte der atlantischen Rasse, waren im Wachstum gleich gut und besser als solche aus den Cevennen (Frankreich) oder Korsika. Die korsischen Herkünfte waren die langsamwüchsigsten, aber in bezug auf Geradschaftigkeit und Kronenform die besten. Gleichzeitig konnten tiefgreifende Unterschiede im Verhältnis des Fruktifizierens der Herkünfte beobachtet werden. Die Herkünfte aus Griechenland und den Cevennen (Frankreich) fruktifizierten zu 60 bis 62%, dagegen diejenigen aus Korsika und Portugal nur zu 22 bis 33%. Ebenso eindrucksvoll waren die Unterschiede zwischen den Versuchsorten. Das beste Wachstum wurde in Varetada mit 0,64 m jährlichem Zuwachs erreicht, das schlechteste auf Sandböden in Kounoupeli mit 0,36 m. Die Leistung wurde eindeutig durch die Herkünfte bestimmt, wobei es keine signifikanten Interaktionen zwischen Provenienz und Standort gab.


## Introduction

Maritime pine (*Pinus pinaster* Ait.) was planted in Greece in 1913 (Michopoulos, 1931). A few trees from that first introduction are growing in the Arboretum of Vetina, Central part of Peloponnese and in a small stand of 4.0 ha in northwestern part of Peloponnese, close to the village of Metochi Achaias. In 1952 small experimental plantings were established in various parts of Greece and from 1967 the species has been extensively used by the Forest Service in large scale reforestation programmes (Gogos, 1978). The question of provenance was ignored, although the species is variable and several races have been recognized since 1928 (Mirov, 1967; Magini and Tulstrup, 1955).

The wide range and diverse environments to which this species has adapted itself provides a large array of geographic variations. In a recent study based on morphological, anatomical and phenological characteristics Resch (1974) distinguished five distinct races: the "Atlantic" race of southwest France and Portugal, the "mesogeensis" (= provincial) race of south France and Italy, the "corteensis" (= corsicana = hamiltonii) race of Corsica, the "maghrebiana" race of Marocco and the "renou" race of Algero-Tunisia.

The natural distribution of the species has been described by many investigators (Mirov, 1967; Krugman and Jenkinson, 1974) and a complete map has been presented by Rodriguez (1966).

The purpose of this paper is to study provenance variation in survival, total tree height, stem diameter at breast height, stem straightness, crown form and proportion of fruiting trees of 9-year-old (ten from seed) provenance tests of *Pinus pinaster* planted on seven sites in Greece. The effect of site and the site × provenance interaction were also studied.

## Materials and Methods

### *Plant material*

The data used in this study were obtained from a trial of seven maritime pine provenances grown in central and southern Greece. Seed of the four provenances from which the experimental plantings were established had the following origins (Cooling, 1977).

| Provenance | Seed Origin | Race (Resch, 1974) |
|---|---|---|
| 1 | Gironde, Landes France | Atlantic |
| 2 | Cevennes, France | Mesogeensis (= Provincialis) |
| 3 | Island of Corsica | Corsican |
| 4 | Portugal | Atlantic |

### *Experimental Design and Establishment*

Seeds of the four provenances were sown in spring 1970 in Lapa nursery in plastic pots filled with a mixture 1:1:1 of soil, sand and manure. One year later in spring 1971 the seedlings were transplanted at the seven locations shown in *Figure 1*. A randomized block design with four replications per location was used for six plantings; for the Kounoupeli planting a completely random design was used with 120 trees per provenance. The experimental plot comprised twenty seedlings arranged in two rows within each plot at 2 × 2 meters spacing. Varetada planting was an exception because of limitations in planting stock; 10-tree-plots were used.

In all cases the trees were kept weed-free for one year by hand.

[1]) Forest Research Institute, Terma Alkmanos, Athens Greece, 615

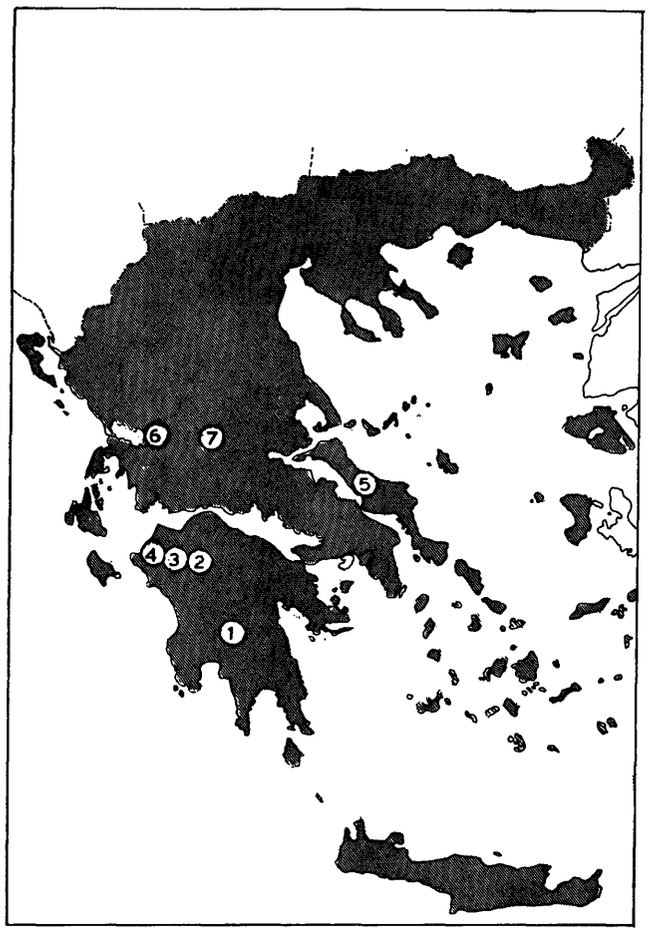


*Figure 1.* — Map of Greece showing the locations of the experimental plantings.

*Measurements*

Measurements of height were taken annually for all trees. At the end of the ninth growing season in the forest (10 from seed) the following characteristics were assessed:

1. Survival
2. Total tree height
3. Diameter at breast height (DBH)
4. Stem Straightness
5. Crown form
6. Fruiting trees
7. Number of cones per fruiting tree.

Height was measured from the ground to the tip of the leader. Stem diameter dbh was measured using diameter tape. Stem Straightness and crown form were assessed by scoring each tree using a scale of 1 = good and 6 = extremely bad. Stem straightness was scored by assessing degree of sweep, spirality, crook and lean relative to other trees in the trial. Crown form was scored on branch angle, branch diameter, branch length and general crown conformation. All trees in the plantings were scored by the same observer.

*Description of the planting sites*

The locations of the planting sites are shown in *Figure 1.* All were well prepared before planting and were free of competing vegetation. The soil of the sites differed in physical and chemical characteristics (Nakos 1979). The soil Vlachokerasia is derived from metamorphic rocks. Borsi A and Borsi B came from tertiary deposits; Kounoupeli had alluvial soil; Prokopi came from basic igneous rocks and Karpenisi and Varetada developed on flysch. The physical and chemical properties of the planting sites, with their elevation and natural vegetation are given in *Table 1.*

*Statistical Analysis*

Analyses of variance were carried out for all characters and for each location separately. Because of the inbalance due to missing trees the analyses were based on plot means using the model given by Snedecor and Cochran (1967):

$$\bar{X}_{ij\cdot} = \mu + P_i + R_j + PR_{(ij)} + \bar{e}_{ij\cdot}$$

Where: $P_i$ = provenance effect

$R_j$ = replication effect

$PR_{(ij)}$ = provenance × replication effect

$\bar{e}_{ij\cdot}$ = the mean of he $n_{ij}$ deviations

The variance of $\bar{X}_{ij\cdot} = \frac{\sigma^2_w}{\times}$

*Table 1.* — Soil characteristics of the experimental plantings.

| Characteristic | Experimental Sites(1) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Vlachokerasia | | Borsi A | | Borsi B | | Kounoupeli | | Prokopi | | Varetada | |
| | Depth of profile, cm | | | | | | | | | | | |
| | 0-20 | 20-50 | 0-20 | 20-50 | 0-20 | 20-50 | 0-20 | 20-50 | 0-20 | 20-50 | 0-20 | 20-50 |
| Clay (%) | 16.0 | 22.0 | 20.0 | 40.0 | 11.0 | 46.0 | 3.0 | 1.0 | 36.0 | 49.0 | 20.0 | 22.0 |
| Silt (%) | 25.0 | 31.0 | 26.0 | 26.0 | 38.0 | 35.0 | 0.0 | 2.0 | 31.0 | 20.0 | 31.0 | 32.0 |
| Sand (%) | 59.0 | 47.0 | 54.0 | 32.0 | 51.0 | 19.0 | 97.0 | 97.0 | 33.0 | 41.0 | 49.0 | 46.0 |
| pH | 5.9 | 5.8 | 5.6 | 5.5 | 6.0 | 7.2 | 8.2 | 8.3 | 6.4 | 6.1 | 6.0 | 5.2 |
| Organic matter (%) | 2.3 | 1.1 | 2.7 | 1.0 | 4.8 | 1.7 | 0.3 | 0.2 | 8.3 | 2.2 | 4.7 | 2.7 |
| Ca (Meq.%) | 3.5 | 4.3 | 9.5 | 13.5 | 10.0 | 36.0 | 19.0 | 18.5 | 6.2 | 2.2 | 6.0 | 4.7 |
| Mg (Meq.%) | 1.5 | 1.7 | 3.5 | 6.2 | 2.3 | 2.2 | 2.5 | 2.4 | 16.1 | 19.3 | 1.7 | 1.4 |
| K (Meq.%) | 0.4 | 0.4 | 0.6 | 0.5 | 1.2 | 0.8 | 0.2 | 0.1 | 0.9 | 0.5 | 0.3 | 0.7 |
| B.E.C. | 40.0 | 31.0 | 26.0 | 30.0 | 23.0 | 37.0 | 7.2 | 5.2 | 27.0 | 30.0 | 27.0 | 23.0 |
| B.S. | 15.5 | 20.7 | 52.0 | 67.0 | 58.0 | >100.0 | >100.0 | >100.0 | 85.0 | 75.0 | 33.0 | 33.0 |
| Elevation (m) | 760 | | 160 | | 120 | | 5 | | 80 | | 350 | |
| Mother rock | Schist | | Tertiary deposits | | Tertiary deposits | | Alluvial | | Igneous | | Flysch | |
| Natural vegetation | Arbudus Erica | | Erica | | Arbudus | | Openings in old pinus halepensis stands | | | | Arbudus Quercus ilex. | |

(1) The planting of Agios Nikolaos Karpenisi was at an elevation 1180 m and established in an *Abies* stand. This planting was severely effected by flost and snowbreak and no soil analysis data is given.

*Table 2.* — Survivals in nine successive years of *Pinus pinaster* provenances at seven locations in Greece.

| Experimental planting | Provenance (1) | Survivals (%) in year 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 |
|---|---|---|---|---|---|---|---|---|---|---|
| VLACHOKERASIA | 1 | | 98 | 98 | 98 | 98 | | | | 98 |
| | 2 | | 95 | 95 | 95 | 95 | | | | 95 |
| | 3 | - | 100 | 100 | 100 | 100 | - | - | - | 100 |
| | 4 | | 98 | 98 | 98 | 98 | | | | 98 |
| | $\bar{x}$ | | 98 | 98 | 98 | 98 | | | | 98 |
| BORSI A | 1 | 96 | 96 | 96 | 93 | 73 | | | | 70 |
| | 2 | 93 | 91 | 91 | 79 | 41 | | | | 41 |
| | 3 | 98 | 98 | 98 | 78 | 54 | - | - | - | 51 |
| | 4 | 98 | 98 | 96 | 89 | 60 | | | | 60 |
| | $\bar{x}$ | 96 | 96 | 95 | 84 | 57 | | | | 56 |
| BORSI B | 1 | 93 | 90 | 86 | 86 | 85 | | | | 85 |
| | 2 | 89 | 80 | 80 | 80 | 80 | | | | 80 |
| | 3 | 98 | 98 | 98 | 96 | 96 | - | - | - | 96 |
| | 4 | 95 | 90 | 90 | 90 | 90 | | | | 90 |
| | $\bar{x}$ | 93 | 89 | 88 | 88 | 88 | | | | 88 |
| KOUNOUPELI | 1 | | 97 | 97 | 97 | | | | | 97 |
| | 2 | | 98 | 98 | 98 | | | | | 98 |
| | 3 | - | 98 | 98 | 98 | - | - | - | - | 98 |
| | 4 | | 97 | 97 | 97 | | | | | 97 |
| | $\bar{x}$ | | 98 | 98 | 98 | | | | | 98 |
| PROKOPI | 1 | 90 | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 |
| | 2 | 66 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 |
| | 3 | 93 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 |
| | 4 | 80 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 |
| | $\bar{x}$ | 82 | 78 | 76 | 78 | 78 | 78 | 76 | 78 | 78 |
| VARETADA | 1 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| | 2 | 100 | 98 | 95 | 93 | 90 | 90 | 90 | 90 | 90 |
| | 3 | 100 | 100 | 98 | 93 | 93 | 93 | 93 | 93 | 93 |
| | 4 | 98 | 98 | 95 | 95 | 93 | 93 | 93 | 93 | 93 |
| | $\bar{x}$ | 99 | 99 | 97 | 95 | 94 | 94 | 94 | 94 | 94 |
| AGIOS NIKOLAOS KARPENISI | 1 | 98 | 95 | 88 | 80 | 60 | 48 | | 38 | |
| | 2 | 98 | 95 | 83 | 75 | 50 | 50 | | 28 | |
| | 3 | 90 | 85 | 63 | 48 | 38 | 35 | - | 28 | - |
| | 4 | 98 | 63 | 18 | 10 | 3 | 3 | | 0 | |
| | $\bar{x}$ | 96 | 84 | 63 | 53 | 38 | 34 | | 31 | |

(1) 1 Landes, 2 Gevennes, 3 Corsican, 4 Portuguese, $\bar{x}$ weighted mean.

Where: $\sigma^2_w$ is within plot variance and K is the harmonic mean of plants per plot.

The $\sigma^2_w$ was estimated by pooling within plot variance over all plots.

For the Kounoupeli planting where a completely random design was used the analyses were based on individual tree measurements.

Statistical analyses of survivals percent, and percent of cone bearing trees were done after transformation of the original data to arcsin square root of proportions.

The results from the Karpenisi planting, because of the low survival, lacked statistical precision and were not analyzed.

Following the analyses by locations, the data were pooled over all locations and a combined analysis for each character was obtained following the procedures outlined by COCHRAN and COX (1968). Expected mean squares for the combined analyses are given by STONECYPHER (1966) and SAMUEL and JOHNSTONE (1978).

## Results and Discussion

### *Survival*

The percentage of surviving trees for the four provenances at each location are given in *Table 2.* Survival after the first year were high, from 66 percent (Provenance 2 at Prokopi) to 100 percent. Survival varied with site ranking from 82 percent at Prokopi to 99 percent at Varetada.

The analysis of variance in percentage survival at nine years for five of the seven locations is given in *Table 3.* Significant differences were found among provenances at Borsi A, Borsi B und Prokopi. In the Karpenisi planting all trees of Portuguese provenance died. Forty five percent of the total losses in this provenance were caused by the severe winter of 1972, when the temperature dropped to −12.6° C. The mean survival of all provenances at this site was 31 percent and trees were bush-like with broken tops and branches due to snowfall. Maritime pine cannot be successfully grown at Karpenisi because low temperatures and snowfall eliminate the species even on sites with favorable soil conditions.

The small number of surviving trees at Borsi A planting (56 percent) after the ninth year is attributed to the drought

*Table 3.* — Analyses of Variance of percentage survival in 9-year-old provenance tests of *Pinus pinaster.*

A. ANALYSIS BY LOCATION

| Source of Variation | D.F. | Mean Squares (1) Vlachokerasia | Borsi A | Borsi B | Varetada | Procopi |
|---|---|---|---|---|---|---|
| Replications | 3 | 321.94 | 239.57 | 192.08 | 321.94 | 130.56 |
| Provenances | 3 | 182.39 | 337.84* | 255.38* | 182.39 | 380.79* |
| Error | 9 | 54.66 | 80.76 | 53.76 | 54.66 | 67.72 |

B. COMBINED ANALYSIS

| ANALYSIS OF VARIANCE | | | DUNCAN NEW MULTIPLE RANGE TEST (2) Location (3) | Survival % (Arcsin) |
|---|---|---|---|---|
| Locations (L) | 5 | 907.21** | 4 | 83.4 |
| Reps./Loc. | 15 | 200.00 | 1 | 82.7 |
| Provenances (P) | 3 | 90.29 | 6 | 80.3 |
| P X L | 15 | 30.01 | 5 | 61.7 |
| P X R/L | 45 | 62.32 | 3 | 57.0 |
| | | | 2 | 48.7 |

(1) * Significant at the 0.05 probability level.
** Significant at the 0.01 probability level.

(2) Any two means not connected by the same line differ at the 0.05 probability level.

(3) 1 Vlachokerasia, 2 Borsi A, 3 Borsi B, 4 Kounoupeli, 5 Prokopi, 6 Varetada.

*Table 4.* — Total tree height, standard deviation (SD) and coefficient of variation (cv) in nine successive years of *Pinus pinaster* provenances grown at six locations in Greece. Diameter at breast height at nine year is also shown.

| Experimental planting | Pron.(1) | Height (cm) in year | | | | | | | | | | | | | | | | | | | | | | DBH(mm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1971 | | | 1972 | | | 1973 | | | 1974 | | | 1975 | | | 1976 | | | 1977 | | | 1978 | | | 1979 | | | 1979 | | |
| | | x̄ | SD | CV | x̄ | SD | CV | x̄ | SD | CV | x̄ | SD | CV | x̄ | SD | CV | x̄ | SD | CV | x̄ | SD | CV | x̄ | SD | CV | x̄ | SD | CV | x̄ | SD | CV |
| VLACHOKERASIA | 1 | | | | 52 | 18,5 | 36 | 86 | 31.6 | 37 | 136 | 51.9 | 38 | 188 | 66.9 | 35 | | | | | | | | | 406 | 93.5 | 23 | 62 | 22.2 | 36 |
| | 2 | | | | 52 | 14,2 | 27 | 87 | 24.3 | 28 | 135 | 41.5 | 31 | 185 | 56.2 | 30 | | | | | | | | | 401 | 89.9 | 22 | 60 | 19.5 | 33 |
| | 3 | | | | 49 | 17.6 | 36 | 85 | 26.0 | 31 | 134 | 37.5 | 28 | 182 | 43.1 | 24 | | | | | | | | | 383 | 71.8 | 19 | 68 | 19.7 | 30 |
| | 4 | | | | 60 | 16.8 | 28 | 96 | 25.9 | 27 | 148 | 40.9 | 28 | 202 | 54.4 | 27 | | | | | | | | | 400 | 86.9 | 22 | 62 | 21.1 | 34 |
| | weight. mean | | | | 53 | 17.3 | 33 | 88 | 27.3 | 31 | 134 | 37.5 | 28 | 189 | 56.0 | 30 | | | | | | | | | 397 | 85.9 | 22 | 63 | 20.8 | 33 |
| BORSI A | 1 | 30 | 10.2 | 34 | 87 | 24.2 | 28 | 152 | 39.0 | 26 | 226 | 80.1 | 35 | 277 | 65.7 | 24 | | | | | | | | | 511 | 91.1 | 18 | 73 | 18.2 | 25 |
| | 2 | 24 | 8.5 | 35 | 74 | 22.9 | 31 | 100 | 40.4 | 31 | 191 | 56.2 | 29 | 205 | 64.5 | 31 | | | | | | | | | 370 | 108.3 | 29 | 52 | 22.9 | 44 |
| | 3 | 25 | 8.1 | 32 | 76 | 24.9 | 33 | 132 | 43.4 | 33 | 203 | 57.0 | 28 | 259 | 55.1 | 21 | | | | | | | | | 402 | 123.3 | 31 | 65 | 24.6 | 38 |
| | 4 | 29 | 9.1 | 31 | 85 | 25.4 | 30 | 145 | 42.6 | 29 | 209 | 59.8 | 29 | 247 | 70.5 | 28 | | | | | | | | | 437 | 116.8 | 27 | 62 | 22.1 | 36 |
| | weight. mean | 27 | 9.4 | 36 | 81 | 25.0 | 31 | 140 | 42.2 | 30 | 208 | 59.5 | 29 | 252 | 68.5 | 27 | | | | | | | | | 439 | 120.9 | 28 | 64 | 22.7 | 35 |
| BORSI B | 1 | 19 | 5.1 | 27 | 56 | 14.5 | 26 | 84 | 22.1 | 26 | 116 | 31.5 | 27 | 163 | 43.4 | 27 | | | | | | | | | 408 | 93.8 | 23 | 51 | 16.8 | 33 |
| | 2 | 16 | 4.8 | 30 | 52 | 15.7 | 30 | 78 | 22.8 | 29 | 108 | 29.8 | 28 | 154 | 40.6 | 26 | | | | | | | | | 385 | 90.5 | 24 | 52 | 18.2 | 35 |
| | 3 | 17 | 4.5 | 26 | 51 | 13.7 | 27 | 81 | 24.2 | 30 | 117 | 34.8 | 30 | 157 | 45.6 | 27 | | | | | | | | | 292 | 94.4 | 24 | 61 | 20.7 | 34 |
| | 4 | 19 | 4.4 | 23 | 55 | 14.9 | 27 | 81 | 23.4 | 29 | 114 | 34.7 | 30 | 163 | 45.6 | 28 | | | | | | | | | 416 | 118.4 | 28 | 54 | 19.6 | 36 |
| | weight. mean | 18 | 4.8 | 27 | 54 | 14.8 | 27 | 81 | 23.2 | 29 | 114 | 32.9 | 29 | 162 | 43.9 | 27 | | | | | | | | | 400 | 100.3 | 25 | 55 | 19.3 | 35 |
| KOUNOUPELI | 1 | | | | 58 | 15.2 | 26 | 85 | 19.6 | 23 | 114 | 26.8 | 23 | | | | | | | | | | | | 359 | 93.1 | 26 | 45 | 20.1 | 45 |
| | 2 | | | | 36 | 11.8 | 33 | 55 | 16.4 | 30 | 76 | 23.4 | 31 | | | | | | | | | | | | 284 | 85.0 | 30 | 33 | 18.1 | 55 |
| | 3 | | | | 40 | 12.4 | 31 | 63 | 16.9 | 27 | 84 | 24.2 | 29 | | | | | | | | | | | | 282 | 81.2 | 29 | 38 | 19.0 | 50 |
| | 4 | | | | 42 | 16.0 | 38 | 68 | 24.6 | 36 | 95 | 33.5 | 35 | | | | | | | | | | | | 371 | 125.5 | 34 | 48 | 25.0 | 53 |
| | weight. mean | | | | 44 | 16.2 | 37 | 68 | 22.5 | 33 | 92 | 30.8 | 33 | | | | | | | | | | | | 324 | 105.9 | 33 | 41 | 21.6 | 53 |
| PROKOPI | 1 | 18 | 33.5 | 19 | 40 | 10.3 | 26 | 65 | 16.2 | 25 | 105 | 25.7 | 24 | 174 | 39.1 | 22 | 245 | 51.1 | 21 | 332 | 59.8 | 18 | 400 | 62.4 | 16 | 502 | 71.3 | 14 | 80 | 18.2 | 23 |
| | 2 | 16 | 3.8 | 24 | 33 | 10.7 | 32 | 53 | 15.1 | 28 | 94 | 24.1 | 26 | 155 | 38.5 | 25 | 229 | 49.4 | 22 | 305 | 55.9 | 18 | 373 | 63.3 | 17 | 467 | 72.5 | 16 | 75 | 18.6 | 25 |
| | 3 | 19 | 5.1 | 27 | 40 | 12.9 | 32 | 65 | 18.8 | 29 | 99 | 28.5 | 29 | 156 | 42.1 | 27 | 227 | 58.0 | 26 | 303 | 65.3 | 22 | 370 | 71.5 | 19 | 450 | 85.9 | 19 | 73 | 19.4 | 27 |
| | 4 | 17 | 2.9 | 17 | 35 | 8.8 | 25 | 59 | 12.9 | 22 | 93 | 20.1 | 22 | 156 | 35.3 | 23 | 226 | 46.4 | 21 | 322 | 59.4 | 18 | 394 | 68.4 | 17 | 482 | 76.3 | 16 | 76 | 17.8 | 23 |
| | weight. mean | 18 | 4.1 | 23 | 38 | 11.2 | 29 | 62 | 16.3 | 26 | 99 | 25.3 | 26 | 161 | 36.6 | 23 | 232 | 52.1 | 22 | 317 | 64.4 | 20 | 384 | 67.8 | 18 | 475 | 79.3 | 17 | 76 | 18.6 | 24 |
| VARETADA | 1 | 31 | 7.4 | 24 | 102 | 21.4 | 21 | 157 | 30.3 | 19 | 226 | 39.6 | 18 | 294 | 48.8 | 17 | 395 | 58.4 | 15 | 462 | 59.4 | 13 | 525 | 64.9 | 12 | 610 | 72.1 | 12 | 90 | 17.9 | 20 |
| | 2 | 26 | 8.4 | 32 | 91 | 19.4 | 21 | 144 | 31.0 | 22 | 212 | 41.8 | 20 | 283 | 51.9 | 18 | 382 | 62.9 | 16 | 451 | 62.8 | 14 | 509 | 71.6 | 14 | 585 | 81.1 | 14 | 88 | 22.1 | 25 |
| | 3 | 24 | 6.1 | 25 | 81 | 17.8 | 22 | 127 | 31.8 | 25 | 183 | 45.7 | 25 | 254 | 55.8 | 22 | 339 | 69.3 | 20 | 411 | 64.5 | 16 | 467 | 77.5 | 16 | 539 | 85.9 | 16 | 91 | 24.7 | 27 |
| | 4 | 24 | 6.2 | 26 | 96 | 21.5 | 22 | 142 | 34.5 | 24 | 203 | 55.2 | 27 | 277 | 69.6 | 25 | 372 | 90.3 | 24 | 445 | 94.2 | 21 | 507 | 102.4 | 20 | 579 | 113.5 | 20 | 89 | 28.7 | 32 |
| | weight. mean | 26 | 7.7 | 30 | 93 | 21.3 | 23 | 143 | 33.4 | 23 | 206 | 48.2 | 23 | 277 | 58.3 | 21 | 372 | 73.4 | 20 | 443 | 73.3 | 17 | 502 | 82.5 | 16 | 580 | 91.9 | 16 | 90 | 23.4 | 26 |

(1) 1. Landes, 2 Cevennes, 3. Corsican, 4 Portugal.

of 1975, when the summer rainfall from June to September was only 17.1 mm. It is worth mentioning that the capacity of the soil to hold water is quite low. The losses from drought varied among provenances considerably *(Table 2)*. Large scale drought desiccation has been also reported in Maritime pine at Gerakini northern Greece, during the exceptionally dry years of 1974 and 1977 (HATZISTATHIS, 1980). The native *Pinus halepensis* and *Pinus brutia* grown under the same conditions were extremely resistant to desiccation.

*Growth and Quality Characters*

The mean total tree heights by provenance and location in the successive years of measurements are presented along with their standard deviations in *Table 4*. Mean dbh at nine years is also shown.

Total tree height varied from site and some differences among provenances were detected.

The analyses of variance at nine years *(Table 5)* revealed that there are differences among provenances at Borsi A, Varetada and Kounoupeli. At these three locations the provenances from Landes and Portugal, representing the Atlantic race, were significantly superior to those representing the Mesogeensis and Corsican races. At nine year the Corsican provenance was the poorest at four out of six plantings. These results agree with those found in the literature. In provenance trials in western Australia from seed originating from Portugal, Landes, Esteril and Corsica showed that the Portuguese provenance was best, followed by the Landes provenance (which according to RESCH, 1974 also belongs to the Atlantic race), while the Corsican provenance was poorest in growth (HOPKING, 1969). The Portuguese provenance was the most vigorous among provenances grown in New Zealand (HARRIS *et al.*, 1976). South Africa (MAGINI and TULSTRUP, 1955), North Africa (BELLEFONTAIN, 1975) and was in the top ranking among 24 provenances tested in Spain (RODRIGUEZ, 1966).

Combined analyses of variance over all locations *(Table 6)* showed significant differences among locations for all characters studied. Significant differences were also detected among provenances in total tree height, stem straightness and crown form, but no significant provenance by location interaction was found, indicating genetypic stability of the provenances tested. This agrees with results reported by BUTCHER (1974 a) who found genotypic stability in several families tested on six sites in Western Australia. Butcher concluded that only one population is needed for afforestation in Western Australia. Provenance stability in this species has been reported by HARRIS (1966). He found that the Portuguese race gave best growth in all experimental plantings. This race was also the best in South Africa and since 1937 it has been used almost ex-

*Table 5.* — Analyses of Variance for Tree Height, Stem Diameter, Stem Straighness and Crown Form at 9-years.

| Source of Variation | D.F. | Mean squares | | | | |
|---|---|---|---|---|---|---|
| | | Vlach. | Borsi A | Borsi B | Prokopi | Varetada |
| | | HEIGHT | | | | |
| Replications | 3 | 0.6490 | 0.7823 | 0.7378 | 0.0342 | 0.1020 |
| Provenances | 3 | 0.0399 | 1.3793* | 0.0931 | 0.1944 | 0.3471** |
| Reps X Provenance | 9 | 0.0546 | 0.4829* | 0.0682 | 0.1951* | 0.0632 |
| Within Plot (1) | | 0.0372 | 0.0984 | 0.0488 | 0.0911 | 0.0323 |
| | | STEM DIAMETER | | | | |
| Replications | 3 | 20.39 | 56.21 | 152.24 | 205.26 | 7.59 |
| Provenances | 3 | 57.39 | 285.66 | 101.63 ** | 32.76 | 8.68 |
| Reps X Provenance | 9 | 24.56 | 117.36* | 31.43 | 94.64 | 42.89 |
| Within Plot (1) | | 21.91 | 51.69 | 18.36 | 58.72 | 19.37 |
| | | STRAIGHTNESS | | | | |
| Replications | 3 | 0.0708 | 0.0050 | 0.1173 | 0.0456 | 0.0623 |
| Provenances | 3 | 0.5075 ** | 1.6616** | 0.9756** | 0.4123** | 1.2423** |
| Reps X Provenance | 9 | 0.0269 | 0.0233 | 0.0984 | 0.0400 | 0.0522 |
| Within Plot | | 0.0242 | 0.1011 | 0.0463 | 0.0594 | 0.0305 |
| | | CROWN FORM | | | | |
| Replications | 3 | 0.0316 | 0.0689 | 0.1450 | 0.0756 | 0.1539 |
| Provenances | 3 | 0.2283** | 1.4789** | 0.5283** | 0.5656** | 0.4716** |
| Reps X Provenance | 9 | 0.0222 | 0.1856 | 0.1131 | 0.0206 | 0.0839 |
| Within Plot | | 0.0221 | 0.1407 | 0.0535 | 0.0597 | 0.0325 |
| | | For all characteristics of the same location | | | | |
| Within plot D.F. | | 296 | 165 | 265 | 234 | 134 |
| Harmonic mean per pot | | 19.5 | 8.1 | 17.3 | 15 | 9.3 |

(1) Within-plot mean squares were divided by the harmonic means per plot.

*Table 6.* — Analyses of Variance for Tree Height, Stem Diameter, Stem Straightness and Crown Form in 9-year-old Provenance Maritime pine grown at six locations.

| Source of variation | D.F. | Mean Squares[1] Height | Diameter | Straightness | Crown Form |
|---|---|---|---|---|---|
| Locations (L) | 5 | 3.018** | 1113.668** | 6.824* | 0.997** |
| Reps/Loc | 15 | 0.344 | 88.338 | 0.060 | 0.095 |
| Provenances (P) | 3 | 0.385* | 61.738 | 1.260** | 0.785** |
| P X L | 15 | 0.071 | 20.872 | 0.0297 | 0.0318 |
| P X R / L | 45 | 0.173 | 61.176 | 0.0482 | 0.085 |
| Within plot | 1094 | 0.055 | 29.516 | 0.0467 | 0.054 |

DUNCAN NEW MULTIPLE RANGE TEST[2]

1. Locations

| Loc. | Ht | Loc. | DBH | Loc. | Str. | Loc. | Crown |
|---|---|---|---|---|---|---|---|
| 6 | 5.80 | 6 | 9.0 | 2 | 3.97 | 1 | 4.17 |
| 5 | 4.75 | 5 | 7.6 | 1 | 3.95 | 6 | 4.12 |
| 2 | 4.39 | 2 | 6.4 | 6 | 3.57 | 2 | 3.90 |
| 3 | 4.00 | 1 | 6.3 | 3 | 3.47 | 5 | 3.60 |
| 1 | 3.97 | 3 | 5.5 | 5 | 3.38 | 4 | 3.55 |
| 4 | 3.24 | 4 | 4.1 | 4 | 3.12 | 3 | 3.15 |

2. Provenances

| Prov. | Ht. | Prov. | Str. | Prov. | Crown |
|---|---|---|---|---|---|
| 1 | 4.66 | 1 | 3.90 | 2 | 3.99 |
| 4 | 4.47 | 2 | 3.82 | 1 | 3.91 |
| 2 | 4.11 | 4 | 3.40 | 4 | 3.61 |
| 3 | 4.08 | 3 | 2.90 | 3 | 3.19 |

(1) * Significant at the 0.05 probability level.
** Significant at the 0.01 probability level.
(2) Any two means not connected by the same line differ at the 0.05 level.

clusively in afforestation projects (MAGINI and TULSTRUP, 1955).

Significant differences were found at the 0.01 level among provenances in stem straightness and crown form. The poorest grown Corsican provenance was best in stem straightness and crown form followed by the Portuguese provenance. Landes and Cevennes were similar and differed statistically from the Portuguese and Corsican provenances. The superiority in stem straightness of the Corsican provenance was also reported by HARRIS (1966). However, this feature is not of practical importance, since the Portuguese provenance is superior in growth and straightness-a highly inherited trait can be improved by selecting within this provenance. Considerable improvement of this character has been made by selection in the native stands of Leira Forest in Portugal (BUTCHER, 1974 b).

*Table 7.* — Percentage of Fruiting Trees and Number of Cones per Fruiting tree in nine-year-old Maritime pine provenances grown at six locations.

| Location | Proportion (%) of fruiting trees by Provenance[1] 1 | 2 | 3 | 4 | $\bar{X}$ | Cones per fruiting tree by provenance[1] 1 | 2 | 3 | 4 | $\bar{X}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Vlachokerasia | 63 | 66 | 35 | 26 | 47 | 3.0 | 3.6 | 2.5 | 2.2 | 3.0 |
| Borsi A | 86 | 56 | 35 | 31 | 70 | 3.2 | 3.7 | 1.9 | 2.1 | 2.2 |
| Borsi B | 32 | 46 | 8 | 17 | 24 | 1.7 | 1.8 | 1.2 | 1.3 | 1.7 |
| Kounoupeli | 58 | 64 | 15 | 52 | 45 | 3.4 | 4.5 | 2.3 | 2.7 | 2.9 |
| Prokopi | 57 | 67 | 29 | 34 | 46 | 3.6 | 4.4 | 2.3 | 2.7 | 3.3 |
| Varetada | 98 | 92 | 27 | 57 | 76 | 2.6 | 3.4 | 1.3 | 2.2 | 1.9 |
| Weighted mean | 60 | 62 | 22 | 33 | 44 | 3.0 | 3.8 | 2.1 | 2.3 | 3.0 |
| Total | | | | | | | | | | |
| No of trees | 426 | 376 | 427 | 414 | 1643 | | | | | |
| Trees bearing cones | 257 | 235 | 96 | 138 | 726 | | | | | |
| Number of cones | 777 | 899 | 200 | 316 | 2192 | | | | | |

(1) 1. Landes, 2. Cevennes, 3. Corsican, 4. Portuguese, $\bar{X}$. Weighted mean.

*Fruitfulness*

The proportion of tree bearing cones at nine years by provenance and location appears in *Table 7*. The analyses of variance *(Table 8)* showed that significant differences exist among provenances and locations. The most prolific provenances were Landes and Cevennes of France, with 60 and 63 percent of the fruitful trees. The lowest proportion over locations observed in the Corsican provenance in which only 22 percent of trees produced cones. The faster growing Portuguese provenance did not rank high. This was consistent for all locations and no significant provenance × location interaction was found. These results provide evidence that cone production in Maritime pine is under genetic control. This characteristic is important in seed orchards where the seed trees should be heavy seed producers. Large variation in fruitfulness of Slash pine has been reported by GODDARD (1964) who found that provenances from the central portion of range flowered more abundantly than other provenances. Furthermore, genetic control of fruitfulness in slash pine has been determined by VARNELL, SQUILLACE and BENGTSON (1975) who estimated broad sence heritability 0,49 for flowering and 0. 50 for cone production.

The variation among locations was significant at the 0.05 level; the Borsi B planting had the lowest number of fruiting trees (24 percent) while Varetada was top (76 percent). The number of cones per fruiting tree was also varied among provenances and locations *(Table 7)*. Cones were more abundant in the Landes and Cevennes provenances with 3 and 3.8 cone respectively and lower in the Portuguese (2.3) and Corsican (2.1) provenances. Correlation coefficients between number of cones per tree and tree height and between number of cones per tree and stem diameter were not significant.

*Table 8.* — Analyses of Variance of percentage of fruiting trees in 9-year-old provenances of Maritime pine grown at six locations. Analyses by location and locations combined. Data transformed to arcsin.

A. ANALYSES BY LOCATION

| Source of variation | D.F. | Mean Squares[1] Vlachok. | Borsi A | Borsi B | Varetada | Prokopi |
|---|---|---|---|---|---|---|
| Replications | 3 | 40.339 | 286.086 | 37.074 | 75.799 | 366.605 |
| Provenances | 3 | 607.258* | 1775.782** | 635.152* | 490.462** | 1764.945** |
| Error | 9 | 89.155 | 195.891 | 92.372 | 31.830 | 106 632 |

| | | B. COMBINED ANALYSIS[2] | Prov. | DUNCAN TEST[3] Fruiting trees (%) | Loc. | Fruiting trees (%) |
|---|---|---|---|---|---|---|
| Locations (L) | 5 | 188.969* | 2 | 54.4 | 6 | 48.8 |
| Reps/Loc .(R/L) | 15 | 161.580 | 1 | 53.4 | 2 | 44.5 |
| Provenances (P) | 3 | 1236.077** | 4 | 39.9 | 1 | 43.3 |
| P X L | 15 | 53.999 | 3 | 25.6 | 4 | 43.0 |
| P X R/L | 45 | 103.116 | | | 5 | 43.0 |
| | | | | | 3 | 28.5 |

(1) * Significant at the 0.05 probability level.
** Significant at the 0.01 probability level.
(2) In the combined analysis the Kounoupeli planting in which a completely random design was used, is also included.
(3) Any two means not connected by the same line differ statistically at the 0.05. level.

## Conclusions

From the assessments in nine-year-old provenance tests of Maritime pine grown on seven sites in Greece the conclusions are

1. Successful planting of the species in areas such as Agios Nikolaos of Karpenisi is practically impossible due to frost hazands (−14° C) and severe snowbreak of trees.
2. Portuguese and Landes provenances, belonging to the same atlantic race grew faster than those from Cevennes and Corsican provenances. The corsican provenance was top in stem straightness and crown form.
3. The provenance by site interactions were insignificant for all characteristics, indicating genetic stability of the provenances tested. Therefore, selecting within the fast grown Portuguese provenance for height and diameter growth and stem straightness is promising for all environments tested.
4. A large variability was found among provenances and among locations in the proportion of fruiting trees. The proportion among provenances varied from 22 (Corsican) to 62 percent (Cevennes) and among location from 24 (Kounoupeli planting) to 76 percent (Varetada planting).


## Acknowledgements

The author thanks Mr. E. Cooling, FAO Expert, who through project UNSF/FAO/GRE: 20/230, established the plantings. Thanks are also extended to the Hydrology Section of Forest Research Institute, for making available material from the planting of Varetada, and to Mr. Tziovaras, Alexopoulos and Pislis for their help in the various stages of the study. Finally special thanks go to Dr. G. Nakos for analysing the soil samples.


## Literature cited


Bellefontaine, R.: Resultat provisoires des essais d'amélioration génétique a bou safi (Larache). Annales de la Recherche Forestière au Maroc. Barat. Maroc 91—147 (1975). — Butcher, T.: Genotype-environment interaction effects with *Pinus pinaster* in Western Australia. Proc. of the fourth Meeting of Representatives, held at Melbourne, Victoria 4—7 March 1974: 102—108 (1974 a.). — Butcher, T.: Western Australia-Forest Departments. Progress Report. Proc. of the fourth meeting of Representatives, held at Melbourne, Victoria, 4—7 March 1974: 71—73 (1974) b.). — Cochran, W. and G. Cox: Experimental Designs. John Wiley and Sons. Inc. New York (1968). — Goddard, R.: The frequency and abundance of flowering in a young slash pine orchard. Silvae Genetica. 13 (6): 184—186 (1964). — Gogos, A.: *Pinus pinaster* Ait. 1989 *(Pinus maritima)*. Forest Research Institute of Thessaloniki, Greece, Bull. No. 96 (1978). — Harris, A.: Introduction of *Pinus pinaster* in western Australia. FO/FTB-69-9/10 4 pp. Second World Cons. on Forest Tree Breeding , Washington D. C. (1966). — Hatzistathis, A.: Reasons for the inefficacy of afforestation under extreme site conditions in Chalkidiki. Paper presented to the IUFRO Conference held in Thessaloniki, 11 pp. (1980). — Krugman, S. and J. Jenkinson: *Pinus* L. In seed of woody plants in the United States. USDA Forest Service. Agri. Hand. No. 450: 598—638 (1974). — Magini, E. and P. Tulstrup: Tree seed notes. FAO For. Develop. Pap. 5, 354 p. (1965). — Mirov, N.: The genus *Pinus*. The Ronald Press. Co. New York. (1967). — Michopoulos, The Conifers. Athens Greece 214 pp. (1931). — Nakos, G.: Forest soils of Greece: Physical, Chemical and Biological properties. Forest Ecol. Manage., 2: 35—51 (1979). — Resch, T.: Essai de distiction morphologique des races majeures de *Pinus pinaster*. Annales de la Recherche forestière au Maroc. pp. 91—102. *In* R.F.F. No 3 1975 (1974). — Rodriguez, F.: Comportanianto racial de *Pinus pinaster* en el norceste de Espana. Sexto Congreso Forestal Mundial Vol II 1534—1540 (1966). — Samuel C. and R. Johnstone: A study of population and inheritance in Sitka Spruce. I results of glasshouse, nursery and early forest progeny tests. Silvae Genetica 28 (1): 26—32 (1979). — Snedecor, G. and W. Cochran: Statistical Methods. The Iowa State Univ. Press. Ames. Iowa (1967). — Stonecypher, R.: The loblolly pine heritability study. International Paper Co. Southlands Exp. Forest Bainbridge, Georgia. Tech. Bull No. 5 (1966). — Varnell, R. Squillace, A. and G. Bengtson: Variation and heritability of fruitfulness in slash pine. Silvae Genetica 16 (4): 125—128 (1967).


# Frost Resistance and Early Growth of Sequoidendron giganteum seedlings of different origins


By M. Guinon, J. B. Larsen and W. Spethmann
Lower Saxony Forest Research Institute,
Staufenberg, West Germany



(Received 11th December 1981)



## Summary

Frost resistance in 2 year old giant sequoia seedlings was analyzed by an artificial freezing test, in which detached twigs are placed in freezing chambers at different temperatures. The temperature that kills 50% of the twig foliage is called the "frost-killing-point" and is denoted LT50%. The results were compared to damage sustained outdoors by seedlings and support the reliability of the testing methods employed.

The experiment included the open-pollinated offspring of 2 trees growing in Hermeskeil, West Germany, and seedling samples of 22 provenances representing the entire natural range of giant sequoia.

Significant and substantial differences were found in frost resistance, winter damage and in early height. Frost resistance is correlated with outdoor winter damage and elevation, however not with latitude, longitude nor with seedling height. Shoot tip hardness measured by touch is unrelated to frost hardiness .



*Key words:* giant sequoia, provenances, cold hardiness.



*Authors:*
Marylee Guinon, Department of Forestry and Resource Management, University of California, Berkeley, California, 94720 USA. — Jørgen Bo Larsen, Danish Forest Experiment Station, Springforbivej 4, DK-2930 Klampenborg, Denmark. — Wolfgang Spethmann, Lower Saxony Forest Research Institute, 3513 Staufenberg Escherode, West Germany.



## Zusammenfassung

Die Frostresistenz 2jähriger Pflanzen bei 22 Provenienzen von *Sequoiadendron giganteum* wurde mit Hilfe eines Klimakammerfrosttestes ermittelt. Der Test wurde im Herbst während der Abhärtungsphase gemacht, und die Ergebnisse geben daher Auskunft über die Frühfrostresistenz. Die Temperatur, bei der 50% der Zweigbenadelung