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Provenance Variation of *Pinus muricata* Grown in Greece

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Summary

Provenance trials of muricata pine (*Pinus muricata* D. DON) were planted in 1980 and 1983 in 2 locations in Greece. The seed was from the 1978 International Collection. Six (in 1980) and 8 (in 1983) provenances were included in the experimental plantings. Assessments were made at the ages of 12 and 9 years from planting and the following results were obtained.

There are significant differences between provenances for total tree height, diameter at breast height, bark thickness, branch diameter and the percentages of forked trees. In both locations the Mendocino inland blue provenance (provenance 09/2) was the best (average height 9.09 m at the age of 12 years) followed by Sonoma coastal (provenance 08/1). The northern provenance from Humboldt Trinidad Head (provenance 10) was the slowest growing (average height at the age of 12 years 7.51 m) with the higher proportion of forked trees (20% of the total).

It is concluded that muricata pine may have some merit in the hardier sites of higher elevations in Greece (above the optimum sites of radiata pine) and that the best provenance of Mendocino inland (provenance 09/2) must be compared, in common experiments with *Pinus brutia* and *Pinus pinaster.*

Key words: Pinus muricata, provenance, population, variation, correlation, foxtailed trees.

FDC: 232.12; 165.5; 174.7 *Pinus muricata;* (495).

Introduction

Pinus muricata D. DON also called bishop or muricata pine is a native species of the west coast of N. America, extending from near the California-Oregon border to northern Baja California of Mexico including the islands of Sanda Gruz and Sanda Rosa (SCOTT, 1960; CRITCHFIELD and LITTLE, 1966; GRIFFING and CRITCHFIELD, 1976; Anonymous, 1978; ELDRIDGE, 1979a). It occurs between latitude 31 at San Vicente in Mexico to 41 N at Trinidad Head at Humboldt County, California. The distribution is very limited and discontinuous. Altitudinally it is found from sea level to about 500 m and usually within 5 km from the coast. It grows in a variety of soils from the best to worst and in cool cloudy areas in the north with annual rainfall 1000 mm. Moisture availability is decreasing from north to south and this change is followed by the associated species (*Pseudotsuga menziesii, Pinus radiata, Quercus agrifolia,* to mixed chaparral scrub in the south). lt is considered as one of the most shade tolerant species of pines that can grow as understory in the north and as overstory in the south (ELDRIDGE, 1979a). It is also very resistant to seawinds and it is considered as an invaliable tree for early shelter in gardens exposed to strong winds (MITCHELL, 1972). Although muricata

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pine belongs to the coastal closed cone pines with serotinous cones, that is considered an advance feature in evolution (SCOTT, 1960; STERN and ROCHE, 1974), it was near to extinction before man intervented and introduced it to new habitats.

Morphologically the species is considered very variable. Early studies by Duffield (FORDE and BLIGHT, 1964) showed that the mainland populations belong to 2 different varieties "blue" and "green" differing in growth, form, bark type, foliage colour and cone shape. The different foliage colour is the result of differences in the shape and waxiness of the chambers above the stomata (MILLAR, 1983).

FORDE and BLIGHT (1964) in an extensive survey of turpentine composition, concluded that the mainland population of muricata pine can be divided into 3 distinct chemical races with separate geographic distribution; the northern blue race, characterized by turpentine consisting entirely of a-pinene (Trinidad Head and Fort Bragg populations). The central green race of Δ-3 carene (south of Anapolis to Monterey). The southernmost green race of sabinene-terpenolene (San Luis Obispo to San Vicente). Finally a fourth green race from Sanda Gruz and Sanda Rosa islands is distinguished, similar to southern mainland population, but with a-pinene as a third constituent. Electrophoretic analyses of fourteen enzyme systems has shown that only in one system, namely glutaminase oxaloacetate transaminase (GOT-1), the blue and green populations were significantly different (MILLAR, 1983); alleles frequency averaged 0.97 in the green stands and decreases to 0.23 in the blue stands and this within only 2.3 km distance.

In Greece muricata pine has been planted, for the first time, in the Arboretum of Vytina in 1918. There are still few trees grown from that introduction. No other attempts were made since that time, because there are many other well adapted coniferous species naturally grown in the country. The International Mission of 1978 (ELDRIDGE, 1979b) which intensively collected muricata pine seed, gave the oportunity for the establishment of the provenance tests in Greece in which the present study is referred. The objectives of the collection were:

1. To provide a long-term and very variable stock of genetic variation in many important characteristics;

2. To provide a resource for selection of plus trees to include in breeding programmes, especially after at least one generation of selection and outcrossing in the new environment and

3. To identify the best Californian sub-populations for each one environment with the purpose of concentrating future selection in the best sub-populations.

Materials and Methods

In 1978 an international team collected seed of muricata pine for consevation and provenance testing (ELDRIDGE, 1979a and b). Within the geographically distinct populations, sub-populations, called in this study provenances, were sampled on the basis of slope, aspect, elevation, soil and occurrence on the

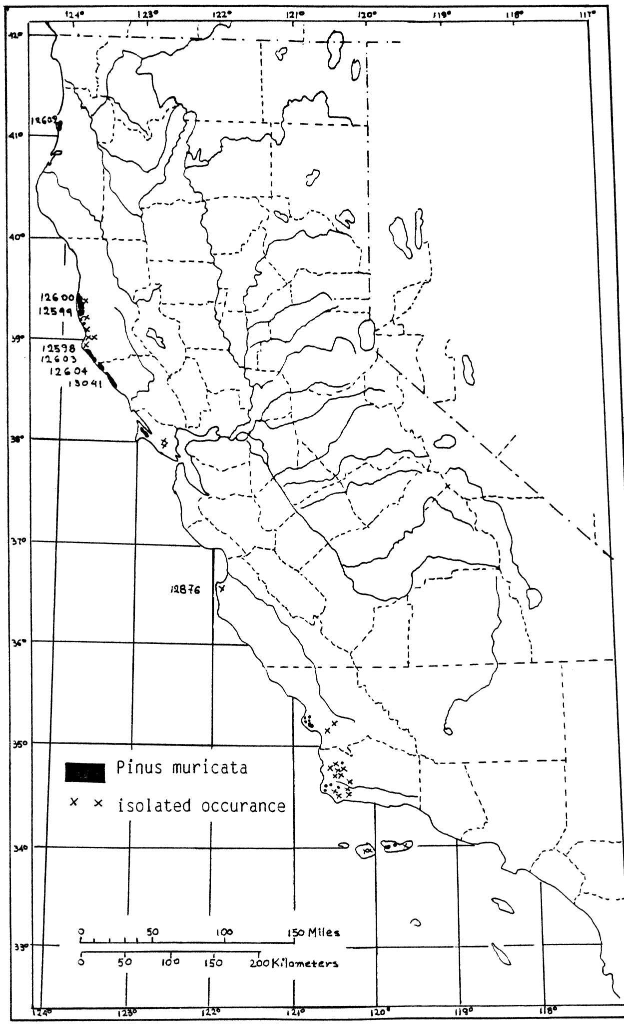

Figure 1. – Geographic distribution of *Pinus muricata* and locations of the provenances tested in Greece. Distribution according to GRIFFING and CRITCHFIELD (1976).

Table 1. – Data of the provenances of *Pinus muricata* used in the experimental plantings in Greece.

No	Provenance Australia	number[1] Greece		Locality	Race	Latit. o	'	Long. o	'	Elev. m.	Seed Trees no
1	12876	26	07	Hukleberry Hill	Green	36	35	121	55	300	12
2	12604	24	08/1	Sonoma Coastal Stewarts pt.	Green	38	38	123	23	50	30
3	13041	27	08/2	Sonoma Inland	Green	38	38	123	22	200	20
4	12598	22	09/1	Mendocino Coastal south pt. Arena	Blue	38	53	123	37	55	24
5	12603	23	09/2	Mendocino Inland, south pt. Arena – Gualala	Blue	38	50	123	35	275	24
6	12600	20	09/3	Mendocino Coastal north, Ft. Bragg	Blue	39	20	123	46	65	20
7	12599	21	09/4	Mendocino Inland, Mendocino – Navarro	Blue	39	15	123	43	250	30
8	12602	19	10	Humboldt Trinidad Head	Blue	41	06	124	07	275	21

[1]) Provenances 12876 and 13041 were included only at Granitsa planting.

coastal or inland side. Between 20 to 40 trees were sampled in each sub-population, at least 100 m apart. From each tree between 40 to 50 cones were collected which were mixed to make the sub-population (provenance). Detailed description of the collection processes is given by ELDRIDGE (1979a).

The provenances used in Greece are given in *table 1* and shown *figure 1*. Emphasis in the collection process was given to northern "blue" provenances, since these are of increasing interest and importance in many parts of the world (Anonymous, 1978).

In fall 1980 2 experimental plantings were established in Raches Arkadias and Vresthena Lakonias (*Table 2*), adjacent to radiata pine plantings that have been already reported (MATZIRIS, 1995). One-year-old seedlings raised in paper pots were used in randomized complete block design including 6 provenances in 7 replications. The experimental unit was comprised of 10 tree row-plot. The spacing was 3 x 3 meters.

Table 2. – Characteristics of the location of the experimental plantings.

Characteristic	Location of the experimental planting Raches	Granitsa
Latitude	37 43	39 07
Longtitude	24 54	25 35
Elevation (m)	605	650
Year of establishement	Oct. 1980	Nov. 1983
Provenances	6	8
Design	RCB	RCB
Replication	7	6
Plot size	10 tree row plot	10 tree row plot
Spacing	3X3 m	3X3 m
Natural vegetation	*Arbudus* *Erica*	*Arbudus* *Erica*
Soil parent materials	Tertiary siliceous deposits	Flysch
Rainfall / year, mm	1100	1440
Summer rainfall, mm	68.5	114
Abs. max,temperature	42	39
Abs. min,temperature	–6	–6

The experimental planting at Vresthena has been destroyed by fire in summer 1988 and is not included in the analyses.

In November 1983 an additional planting was established at the area of Granitsa Evritanias, including the 6 provenances previously used plus 2 new; 1 from Monterey (provenance 07) and 1 from Sonoma inland (provenance 08/2). The characteristics of all experimental plantings are shown in *table 2.*

Measurements

At Raches planting the followed characteristics were measured: Total tree height (HT) at the ages 1, 2, 3, 4, 5, 9, and 12 years. Diameter at breast height (DBH) at the ages 9, 10 and 12 years. At the age of 8 years (October, 1988) several additional characteristics were measured. Bark thickness at breast height (BTH) was estimated as the average of 2 diametrically oposite measurements. Stem straightness (STR) and crown form (CF) were evaluated according to a 5 class scale (1 very good, 5 very poor). The number of whorls (WN) were counted along the stem; the number of foxtailed trees were also counted. A tree was characterized as foxtailed if the leader was unbranched over a length greater than one year's usually height growth. The total number of branches of the fifth whorl from the ground were counted and their diameters at a distance 5 cn from the main stem were measured. The diameter of the thicker branch (DTB) as well as, the mean branch diameter (MBD) of the whorl were calculated and assessed. The number of cones on the main stem and branches were measured and the number of forked trees were recorded.

At the Granitsa location the characteristics measured were total tree height at 6 and 9 years and breast height diameter at the age of 9 years.

Statistical Evaluation

Simple analyses of variance were performed for all characteristics measured or assessed. The analyses were based on plot means. Product moment and SPEARMAN's rank correlations among all combinations of the characteristics were calculated following appropriate procedures (SNEDECOR and COCHRAN, 1967). The number of cones were transformed, to square root plus one, before the analysis, to spread out and normalize the variance.

Results and Discussion

Provenance averages for the Raches planting including mean height, DBH, bark thickness, stem straightness, crown form, number of whorls, number of branchess per whorl, diameter of the thicker branch, mean branch diameter, proportion of forked and foxtailed trees, number of cones and survivals are shown in *table 3*.

Table 3. – Mean values of the characteristics studied at Raches experimental planting.

chara-cteristic[1]	Unit	PROVENANCE NUMBER 10	09/3	09/4	09/1	09/2	08/1	overall mean
HT1	m	0.29	0.33	0.38	0.35	0.39	0.45	0.36
HT2	m	0.55	0.59	0.66	0.64	0.67	0.72	0.64
HT3	m	0.77	0.87	0.95	0.92	1.03	1.03	0.93
HT4	m	1.25	1.44	1.56	1.45	1.67	1.63	1.50
HT5	m	1.92	2.25	2.41	2.32	2.48	2.54	2.32
HT8	m	4.57	4.97	5.05	5.12	5.42	5.16	5.05
DBH8	cm	6.20	6.91	6.98	7.24	7.43	7.78	7.09
HT9	m	5.06	5.67	5.77	6.02	6.25	5.82	5.76
DBH9	cm	7.49	8.29	8.47	8.63	8.97	9.26	8.52
DBH10	cm	8.67	9.61	9.79	9.94	10.57	10.63	9.87
HT12	m	7.51	8.37	8.96	8.56	9.09	8.33	8.47
DBH12	cm	10.47	11.97	12.10	12.21	13.26	12.93	12.16
BTH	mm	3.01	4.12	4.04	4.30	4.18	4.39	4.01
STR	score	2.30	2.07	2.13	2.13	1.97	2.39	2.16
CF	score	2.74	2.39	2.40	2.61	2.34	2.73	2.53
WN	no	11.53	11.62	10.76	10.69	11.64	11.37	11.27
BN	no	6.26	6.13	6.36	6.44	6.75	6.85	6.46
DTB	cm	17.15	18.37	19.30	19.91	20.29	20.59	19.27
MBD	cm	13.98	13.80	15.08	15.02	15.34	15.34	14.76
Cones/tree	no	5.56	4.82	3.42	3.56	3.33	3.90	4.10
SURVIVALS	%	93.00	96.00	96.00	87.00	90.00	99.00	94.20
FORKS	%	20.00	13.40	11.90	17.70	14.90	14.50	15.40
FOXTAILS	%	0.00	4.50	4.50	1.60	4.50	0.00	2.50

[1]) HTi, DBHi total tree heigh and DBH at the age i years respectively. BTH Bark thickness, STR stem staightness, CF crown form, WN number of whorls, BN number of branches per whorl, DTB diameter of the thicker branch in the whorl.

The mean height and DBH for the Granitsa planting are listed in *table 4*. The analyses of variance for all characteristics are presented in *table 5* for the Raches and in *table 6* for the Granitsa.

Table 4. – Means of total tree height at the age of 6 (HT6) and 9 (HT9) years, and DBH at the age of 9 (DBH9) years of *Pinus muricata* experimental planting grown at Granitsa.

Provenance	HT6 m	HT9 m	DBH9 cm
07	2.36	4.45	6.92
08/1	2.49	4.42	7.35
08/2	2.26	4.20	6.90
09/1	2.40	4.52	6.70
09/2	2.50	4.69	6.97
09/3	2.22	4.25	6.27
09/4	2.44	4.38	6.70
10	1.87	3.56	5.12
overall mean	2.32	4.31	6.61

Differences Among Provenances

Growth Characteristics

At Raches the provenance means for total tree height at the age 12 years varied from 7.51 (provenance 10 from Humboldt County) to 9.09 (provenance 09/2 from Mendocino County). The differences among the provenances for height and DBH were statistically significant for all years (*Table 5*). These results are different from those reported by FALKENHAGEN (1991). He found in provenance test grown in South Africa, of exactly the same collection, that the Sonoma provenance (08/1) from Stewart Point was the best in growth at the ages 4 and 8 years. SHELBOURNE et al. (1982) have also found in 6-year-old provenance tests grown in 10 sites in New Zealand, that the Sonoma "green" provenance was the fastest growing at almost all sites, followed by Mendocino "blue", that in both locations in Greece was the best. However, they emphasized that more reliance should be placed on Mendocino "blue", following 75 years experience with this provenance, in New Zealand. In Greece at Raches experimental planting the Sonoma provenance (08/1) was the fastest in growth for the first 5 years, but later on its growth had declined and at the age of 12 years the superiority of the "blue" Mendocino provenance (09/2) was obvious. This provenance was also the best in stem straightness and crown form. Survivals ranged from 87% (provenance 09/2) to 99% (provenance 08/1) with overall mean 94.2% (*Table 3*). There are differences between the southern "green" and northern "blue" populations of muricata pine in many other characteristics. It has been reported by MILLAR (1983) that blue trees flowered earlier than green trees and that no green pollen was shed during the period of blue female strobilus receptivity, but blue pollen was shed almost throughout the whole period of female receptivity. This would favor north to south gene flow and not in the oposite direction. In an other study MILLAR (1989) found that allozyme differences at 7 of 46 loci distinguished blue and green races on different soils.

Table 5. – Analyses of variance of the characteristics studied at Raches experimental plantings.

Characteristics[2]	MEAN SQUARES[1]		
	Reps	Provenances	Reps x provenances
HT1	0.015**	0.021**	0.001
HT2	0.015**	0.021**	0.001
HT3	0.083**	0.070**	0.006
HT4	0.185**	0.161**	0.020
HT5	0.346**	0.352**	0.031
HT8	0.942*	0.546	0.234
DBH8	2.846**	20.390**	0.440
HT9	0.807*	1.137*	0.261
DBH9	2.793**	2.793**	0.592
DBH10	3.789**	3.789**	0.741
HT12	1.743*	2.215*	0.947
DBH12	3.018**	6.569**	1.179
BTH	1.228**	1.779**	0.160
STR	0.146	0.167	0.124
CF	0.169	0.229	0.130
WN	5.244**	1.302	1.442
BN	0.922	0.548	0.678
PTB	12.981**	11.868*	3.670
MBD	3.189	3.317	2.401
Forks	4.841	1.343	2.293

[1]) Degrees of freedom for all characteristics; Reps 6, provenances 5, reps x provenances 30.

*), **) statistically significant at 0.05 and 0.01 probability level respectively.

[2]) HTi, DBHi, total tree height and DBH at the age i years, respectively; BTH bark thickness, STR straightness, CF crown form, WN number of whorls, BN number of branches, DTB diameter of the thicker branch, MBD mean branch diameter of the whorl.

At the Granitsa planting, the differences among provenances in height and DBH were statistically signifcant (*Table 6*). The pattern of differences between provenances at the ages 6 and 9 years remained fairly constant, with Mendocino blue provenance (09/2) being the best (mean height at the age of 9 years 4.68 m) and provenance 10 from Humboldt County being the worst (3.56 m). Mendocino populations are also more resistant to needle blight caused by *Dothistroma septospora* var. *septospora*. ADES et al. (1992) studying provenance tests grown in New South Wales of Australia found a characteristic general trend of increasing susceptibility in provenances progressively southwards along the Californian coast. Camparing their findings with the attitude of radiata pine they suggested that Mendocino provenance of muricata pine can be considered as an alternative to radiata pine on sites where there is a high risk of severe needle blight, as it possesses a combination of high disease resistance, rapid growth rate and according to SCHNIEWIND and GAMMON (1986) desirable wood properties. SIMPSON and ADES (1990) have also found that muricata is more resistant to the aphid *Pineus pini* than radiata pine.

Table 6. – Analyses of variance for total tree height at the age of 6 (HT6) and 9 (HT9) years and breast height diameter at 9 (DBH9) years for the Granitsa experimental planting.

Source of variation	D.F.	MEAN SQUARES[1]		
		HT 6	HT 9	DBH 9
Replications	5	0.341**	28.371**	58.536**
Provenances	7	0.252**	1.088*	3.043*
Prov. x replications	35	0.049	0.433	1.204

[1]) *), **) statistically significant at 0.05 and 0.01 probability level respectively.

Detail description of Mendocino blue provenance (09/2) that has been found the fastest in growth on both locations in Greece is given by ELDRIDGE (1979a). The collection was made along roadsides which run parallel to the coast from Gualala to Point Arena in a distance of 20 km. The furthest tree inland was approximately 6 km from the coast and no trees within 1.5 km of the coast were included in the collection. The elevation was above 170 m from see level.

Branching Characteristics

There were no significant differences among the provenances in the number of whorls produced, the number of branches per whorl and the mean diameter of the branches per whorl (*Table 5*). The differences for the diameter of the thicker branch and for bark thickness were statistically significant at 0.05 and 0.01 probability level respectively. The percentage of forked trees was ranging from 11.9 (provenance 09/4) to 20 (provenance 10 from Humboldt) but the differences were not significant. SHELBOURNE et al. (1982) have found significant differences among provenances in most of the branching characteristics studied.

The production of stems unbranched over a length greater than the one year's usual growth (foxtails) is a common phenomenon to tropical and sudtropical pines (KOZLOWSKI, 1971). The provenance mean values of foxtailed trees were ranking from zero (provenance from Humboldt and Sonoma) to 4.5% (provenances 09/2, 09/3, and 09/4). The overall mean of foxtailed trees was 2.5% (*Table 3*), quite lower from the 3.3% found in radiata pine grown at the same site (MATZIRIS, 1995).

Cone Production

The number of cones produced by provenance at the age of 8 years are shown in *table 3*. The analysis of variance showed that the differences among provenances were not significant. The cones were counted separately according to their position in the trees i. e., cones on the main stem or branches. Of the total number of 1540 cones counted, 70% were formed on the main stem and only 30% were on the branches. The cones persist for many years on the trees and in many cases, stem cones are included in the wood, as diameter grows. This is a disadvantage that decreases the wood quality. In the environment of Raches, 28% of the cones were opened the years followed ripening and 68% remained closed. At the age of 8 years the mean number of cones produced per tree was 4.1,

Table 7. – Product moment (above diagonal line) and SPEARMAN rank (below diagonal line), correlation coefficients of 17 characteristics of *Pinus muricata* at Raches experimental planting.

Char.[1]	HT1	HT2	HT3	HT4	HT5	HT9	DBH9	DBH10	HT12	DBH12	BTH	STR	CF	WN	BN	DTB	MBD
HT1		0.93	0.86	0.83	0.80	0.35	0.71	0.71	0.36	0.69	0.68	0.02	0.06	0.34	0.40	0.67	0.53
HT2	0.94		0.92	0.86	0.86	0.44	0.76	0.74	0.39	0.71	0.72	-0.02	0.15	0.30	0.33	0.73	0.56
HT3	0.87	0.92		0.94	0.94	0.58	0.83	0.82	0.51	0.78	0.78	-0.19	0.05	0.38	0.40	0.77	0.64
HT4	0.83	0.87	0.93		0.95	0.65	0.83	0.83	0.59	0.81	0.76	-0.26	-0.06	0.45	0.38	0.78	0.66
HT5	0.80	0.86	0.94	0.93		0.66	0.86	0.85	0.60	0.82	0.82	-0.25	0.00	0.39	0.37	0.79	0.67
HT9	0.44	0.54	0.64	0.70	0.71		0.78	0.78	0.75	0.79	0.64	-0.49	0.18	0.36	0.27	0.65	0.63
DBH9	0.70	0.76	0.83	0.83	0.86	0.84		0.98	0.65	0.96	0.82	-0.28	0.09	0.51	0.43	0.88	0.77
DBH10	0.70	0.75	0.83	0.83	0.85	0.83	0.98		0.61	0.97	0.82	-0.32	0.06	0.54	0.42	0.87	0.77
HT12	0.38	0.46	0.51	0.61	0.60	0.87	0.69	0.69		0.64	0.36	-0.55	-0.32	0.21	0.19	0.45	0.44
DBH12	0.66	0.70	0.78	0.79	0.80	0.85	0.95	0.96	0.77		0.77	-0.32	-0.02	0.49	0.37	0.85	0.76
BTH	0.68	0.74	0.81	0.74	0.82	0.69	0.82	0.83	0.47	0.78		-0.28	-0.03	0.41	0.31	0.73	0.57
STR	0.12	0.07	-0.10	-0.17	-0.17	-0.43	-0.24	-0.26	-0.42	-0.31	-0.17		0.68	-0.27	0.07	-0.14	-0.26
CF	0.02	0.12	0.05	-0.06	0.00	-0.20	0.02	0.03	-0.24	-0.09	-0.01	0.66		-0.13	0.18	0.23	0.12
WN	0.29	0.29	0.37	0.46	0.37	0.39	0.46	0.51	0.32	0.48	-0.37	-0.33	-0.18		0.09	0.37	0.43
BN	0.36	0.30	0.37	0.32	0.32	0.27	0.40	0.36	0.10	0.32	-0.29	0.20	0.20	0.05		0.44	0.18
DTB	0.69	0.76	0.80	0.80	0.80	0.71	0.87	0.85	0.59	0.84	0.77	-0.09	0.16	0.29	0.46		0.88
MBD	0.51	0.58	0.60	0.63	0.63	0.63	0.71	0.72	0.55	0.72	0.59	-0.19	0.11	0.30	0.15	0.83	

[1]) HTi, DBHi, total tree height and DBH at the age i years, respectively; BTH bark thickness, STR stem straightness, CF crown form, WN number of whorls, BN number of branches, DTB diameter of the thicker branch, MBD mean branch diameter of the whorl. Values greater than 0.304 and 0.393 are statistically significant at the 0.05 and 0.01 probability level, respectively. Degrees of freedom for all values = 40.

ranging among provenances from 3.3 (provenance 09/2) to 5.6 cones (provenance 10).

Relationship Between Characteristics

PEARSON and SPEARMAN's rank correlation coefficients between all combinations of the characteristics are shown in *table 7* for the Raches and in *table 8* for the Granitsa planting. As it was expected, year to year correlations for height growth were strong between consecutive years and their values gradually reduced, as the distance between the years increased. The correlation coefficient for height at ages 1 and 2 years was very strong (r = 0.93), while that between 1 and 12 years reduced to r = 0.36. Similar trend was observed and in the values of SPEARMAN's rank correlations. FALKENHAGEN (1991) has also found strong age to age correlations in height growth in provenance tests grown in South Africa; he found correlations between 4 and 8 years measurements ranging in different sites from r = 0.88 to r = 0.98. Characteristics related to tree size i. e., total tree height, DBH, bark thickness and branch diameter are highly correlated (*Table 7*). Straightness and crown form are loosely correlated with growth characteristics, while they are moderately intercorrelated (r = 0.68). The number of whorls per tree is positively correlated with the growth characteristics, indicating that, as in radiata pine (MATZIRIS, 1995), the fastest growing trees are forming more whorls. As a result of this relationship, when selection for growth is practiced multinodal trees are favored. Branch diameter is positively correlated with the number of whorls (r = 0.43). It is also positively correlated with all growth characteristics with r values ranking from 0.44 to 0.77 (*Table 7*).

Table 8. – Product moment (above diagonal line) and SPEARMAN's rank (below diagonal line), correlation coefficients at Granitsa experimental planting.

Characteristic	HT 6	HT 9	DBH 9
HT 6		0.79	0.86
HT 9	0.81		0.82
DBH 9	0.85	0.80	

Comparison of P. muricata to P. radiata

At Raches experimental planting muricata pine is growing adjacent to radiata pine that has been recently evaluated (MATZIRIS, 1995). As the site is very uniform and both experimental plantings were established at the same time, it is of interest to compare the growth and other characteristics of the 2 species. The overall mean values of the characteristics measured or assessed are shown in *table 9*. It is obvious from the table, that up to the age of 5 years, the height growth of both species was exactly the same. However, latter on the growth of radiata pine had been accelerated and at the age of 12 years the mean height and DBH of muricata pine were only 75.0% and 88.6% of the respective values of radiata pine. These results are in agreement with those reported by SHELBOURNE (1974), who found that in stands in New Zealand, the growth of blue muricata averages about 85% of that of radiata pine, on sites where radiata pine has been proved completely successful; on high elevation, however, muricata pine outperforms the radiata pine, probably because muricata tolerates lower temperatures and extremes and unseasonal frosts better than radiata pine. Muricata also tolerates better snow breakages and infertile poorly drained soils. On such sites, unfavorable for radiata pine, muricata pine must be compaired with the most hardy and most frost tolorant species of *P. brutia* and *P. pinaster*. The Mendocino provenance of muricata pine has been also suggested by ADES et al. (1992) as an alternative to radiata pine for planting on sites where there is a high risk of severe needle blight, as it possesses a combination of high disease resistance and rapid growth.

Table 9. – Mean values of 17 characteristics of *Pinus radiata* and *Pinus muricata* at Raches experimental planting.

Characteristics[1]	*Pinus radiata*		*Pinus muricata*	
	overall mean	S.D.	overall mean	S.D.
HT1	0.50	0.089	0.36	0.074
HT2	0.73	0.115	0.64	0.085
HT3	1.02	0.183	0.93	0.158
HT4	1.53	0.274	1.50	0.247
HT5	2.32	0.393	2.32	0.341
HT9	6.77	0.886	5.76	0.669
HT12	11.16	1.298	8.47	1.104
DBH9	9.74	1.679	8.51	1.079
DBH10	11.33	1.901	9.87	1.240
DBH12	13.73	2.120	12.16	1.451
BTH	3.86	0.602	4.01	0.717
STR	2.33	0.520	2.16	0.364
CF	2.51	0.538	2.53	0.385
WN	10.07	1.467	11.27	1.408
BN	7.08	1.195	6.46	0.835
DTB	22.32	3.716	19.27	2.456
MBD	16.27	2.486	14.76	1.621

[1]) HTi, DBHi, total tree height and DBH at the age i years, respectively. BTH bark thickness, STR stem straightness, CF crown form, WN number of whorls, BN number of branches, DTB diameter of the thicker branch, MBD mean branch diameter of the whorl.

Conclusions

From the analyses of provenance tests of muricata pine grown at 2 locations in Greece the following conclusions can be drawn:

There are significant differences between the provenances of muricata pine, in growth, bark thickness and branching characteristics. Mendocino inland blue provenance (09/2) is the fastest, while the Humboldt Trinidad Head (provenance 10) is the slowest in growth. At the early years (up to the age of 5 years) muricata and radiata pine have the same growth rate. However, later on, muricata is growing much slower. It is therefore recommended that the use of muricata pine in Greece must be restricted only on the hardier sites of higher elevation, where the growth of the faster growing radiata pine is rather problematic.

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Genetic Parameter Estimates for Production and Quality Traits of *Pinus elliottii* ENGELM. var. *elliottii* in Zimbabwe

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Summary

P. elliottii ENGELM. var. *elliottii* is an important exotic plantation species in Zimbabwe, where it is grown for saw-timber and resin production. Two progeny tests, originating from factorial matings between parents selected in plantations, were assessed at 5, 8 and 15 years. This paper reports genetic parameter estimates for important production and quality traits. All traits assessed were under a reasonable degree of additive genetic control, with the magnitudes of non-additive genetic variances almost invariably somewhat less than those of additive genetic variances. Narrow-sense heritabilities for growth traits, wood density and resin yield were moderate to high, ranging from 0.16 to 0.42; those for stem straightness and branching traits were lower, ranging between 0.04 and 0.17. Genetic correlations at each of the assessment ages were more variable; of most consequence for production were the slight negative correlations between wood density and both stem diameter and volume, and the slight positive correlation between density and height. Age-age correlations for growth traits were high, indicating potential for early selection. Age-age correlations for other traits were variable.

Key words: factorial mating design, genetic parameters, progeny tests, *Pinus elliottii.*

FDC: 232.11; 165.4; 174.7 *Pinus elliottii;* (689.1).

1. Introduction

Some 35 000 ha of *Pinus elliottii* ENGELM. var. *elliottii* plantations have been established in Zimbabwe, where the commercial importance of the species is second only to *P. patula* SCHIEDE and DEPPE (Zimbabwe Forestry Commission[4]), pers. comm.). Under Zimbabwean conditions, *P. elliottii* has advantages over

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