PROVENANCE VARIATION IN SEEDLINGS OF PINUS PINASTER.

by

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PROVENANCE VARIATION IN SEEDLINGS.

Summary and Conclusions

Plants of *Pinus pinaster* raised from provenances from Portugal, France, Italy and Corsica were compared for seedling differences within a pot trial in a glasshouse. Comparisons were made within a factorial design which included five plant groups, high and low nutrition treatments and, for one harvest, high and low watering treatments. *Pinus radiata* was included in the trial to allow comparison of variation of attributes measured both between species and within species. Three harvests were made over a period of nineteen months comparing attributes at different stages of seedling development.

Attributes measured at each harvest were root and shoot dry weight, root/shoot ratio and N, P, K concentration of root and shoot tissue. Needle length was measured for Harvests 2 and 3 and proportion of resting (dormant) buds for Harvest 2. For Harvest 3 the number of damaged shoots was assessed for each treatment.

Significant differences occurred between provenances in height growth, dry weight production, concentration of potassium, vigour of terminal buds and extent of shoot mortality. No useful distinctions were obtained for comparisons of means for root/shoot ratio, phosphate concentration, nitrogen concentration and needle length.

Pinus radiata produced superior growth under high nutrient levels but was exceeded by some *P. pinaster* provenances at low nutrient levels. The Portuguese provenance was the most comparable, in growth, to the *P. radiata*.

Attribute means for provenances indicated that variation was continuous within the species with the Leiria R and Leiria 2 and Corsican and Landes pairs being most similar.

Response to potassium nutrition was most pronounced between provenance groups and differences obtained may be of value in future environmental comparisons or of significance to fertiliser testing.

The trial was designed to complement long term field studies and is supported by those results.

Introduction

This paper presents results of a pilot trial with some provenances of *Pinus pinaster*, established in the field program, compared in pots under glasshouse conditions. At the time of planning the trial in 1964 no specific data was available for comparative seedling performance under a range of nutrition and drought conditions.

Provenances Studied

Seed batches in the trial were obtained as representatives of *Pinus pinaster* in Portugal (Leiria), Italy (Lucca), Corsica and France (Landes).

The experiment was commenced with one year old seedlings raised in the nursery and surplus to requirements for a long term field trial (
WP 3/65).

Treatments with seedlings of *Pinus radiata* Don. were also incorporated in the pot trial to provide a standard for comparison. This standard was selected by virtue of the overall importance of the species to Australian forestry and the relatively advanced knowledge of its nature and performance. Its inclusion allowed evaluation of the extent of differences between species and within *P. pinaster*.

At some stage in the seed store or nursery, the Luccan batch was replaced with a more vigorous provenance. This has since been identified, with maturity, as of Portuguese origin and is referred in this trial as Leiria 2. Part of the reason for this trial was to obtain an early comparison of the unusual, supposed, Luccan provenance which appeared to be like a Portuguese provenance in the nursery.

Procedure

Preparation

All seed was sown in August 1963 at the Wanneroo nursery with identical treatment for all provenances. Selection of seedlings from the nursery beds aimed to ensure that differences in nursery fertility and plant type would not influence comparisons between provenances and species.

For each plant group (Genotype) six plants, uniform in size, were transplanted in May 1964 into each can which was 22.9 cm deep and 17.8 cm diameter. A standard potting mix of three parts coarse sand and one part loam was weighed to provide equal weights of mix in each can. Forty such pots were prepared for each of the five seedling groups used.

Design

Following an establishment period of three months the pots were thinned to the four most uniform plants. Average plant height per pot was determined and the pots were allocated to ten uniformity blocks with four pots of each seed origin per block. Uniformity was based on a height ranking with the tallest plants of each genotype in Block I grading to the smallest in Block 10.

Within each block the four pots of common origin were randomly allocated as A, B, C and D to receive the following treatments.

- A - Fertilised, high watering (F, HW)
- B - Not fertilised, high watering (NF, HW)
- C - Fertilised, low watering (F, LW)
- D - Not fertilised, low watering (NF, LW)

Nutrition

The two fertiliser levels were maintained by adding 0.5 litres of liquid fertiliser (23% nitrogen, 4% phosphorus, 10% potassium) to treatments A and C at least once a month during the trial. During summer months of rapid growth and daily watering, fertiliser was added twice a month. Treatments B and D received no added fertiliser during the trial.

Watering

The droughting treatment was applied only to the four blocks used for the second harvest. Pots not involved in this comparison were watered regularly with free bottom drainage.

On 17 February 1965, all pots involved in the four blocks (80 pots) for Harvest 2 were watered thoroughly and allowed to drain overnight. At 8.00 am the following morning the drainage holes in each pot were sealed and the pots weighed on an automatic balance. Each day at 8.00 am the pots were weighed and water added to the high watering treatments (A and B) to return them to the initial drained weight (field capacity). Treatments C and D were permitted to dry to the condition of permanent wilting of contained plants, before re-watering. The point of permanent wilting was assessed as a compromise between visual symptoms of wilt in the shoot and levelling off of daily pot weight (water) loss. Both diagnostic techniques appeared to be equally effective in assessing the permanent wilting point. Only one wilting cycle was imposed and harvesting followed directly after all pots had been re-watered.

Throughout the droughting trial the fertilised, regularly watered treatments were used as an atmometer with the daily water loss providing a measure of the evaporative potential of the environment.

Height growth

Heights of the plants in each pot were measured throughout the trial. Measurement frequency varied from weekly, during periods of active growth, to monthly, during dormant periods.

Harvesting

The trial was potted and placed in the glasshouse in May 1964 and treatments applied in August 1964. Harvests were made for dry weight analyses in November 1964, March 1965 and January 1966. Two blocks, randomly selected, were involved in the first harvest and four in each of the second and third harvests.

Harvesting consisted of cutting the shoots at soil level and grouping the shoots and washed roots from each pot. Shoot and root weights were obtained after drying at 70^{o}c. Both root and shoot dry residues were analysed for nitrogen (N), phosphorus (P) and potassium (K) concentrations.

INSERT FIGURE 1 NEAR HERE

Maximum needle length and shoot condition (health, dormancy) were recorded for each plant during harvesting.

Results

A. Harvest 1

Plants were 15 months of age at harvest with 3 months exposure to fertiliser treatments.

Height Growth - Seedling heights were measured at approximately fortnightly intervals. During this measurement the condition of the buds and plants was recorded to observe any obvious differences between provenance performance. Some shoot deaths were noted in January 1965 and the number increased as the trial progressed. This mortality and the necessity to thin pots from four plants to two in May 1965, complicated height comparisons for the entire trial period. Consistent and reliable height measurements were available, however, for the period July 1964 to April 1965.

Results (Figure 1) showed the Leiria R and Leiria 2 provenances to be superior in height growth to the Corsican and Landes groups; both for fertilised and non fertilised conditions. The Leiria growth was almost identical to that of *P. radiata* over the period.

Plant Dry Weight - Treatment effects were highly significant (.001 level) for both shoot and root data (Table 1). The genotype by fertiliser (GxF) interaction for shoot tissue was also significant resulting from either an uncharacteristic, higher non fertilised value for the Leiria R genotype or a lower than expected value with fertiliser (Fig. 2). Removal of the Leiria R data from the set gave similar results for main effects but no interaction was

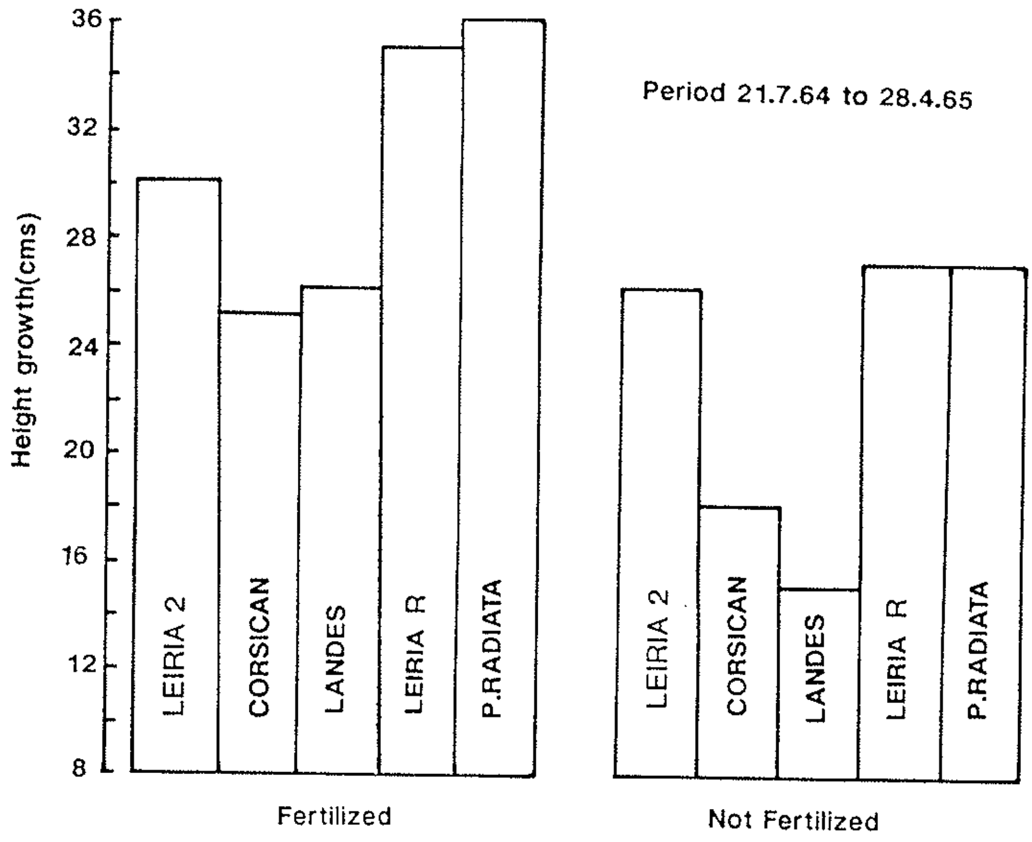

Figure 1.

Mean height growth for seedlings in the pot trial.

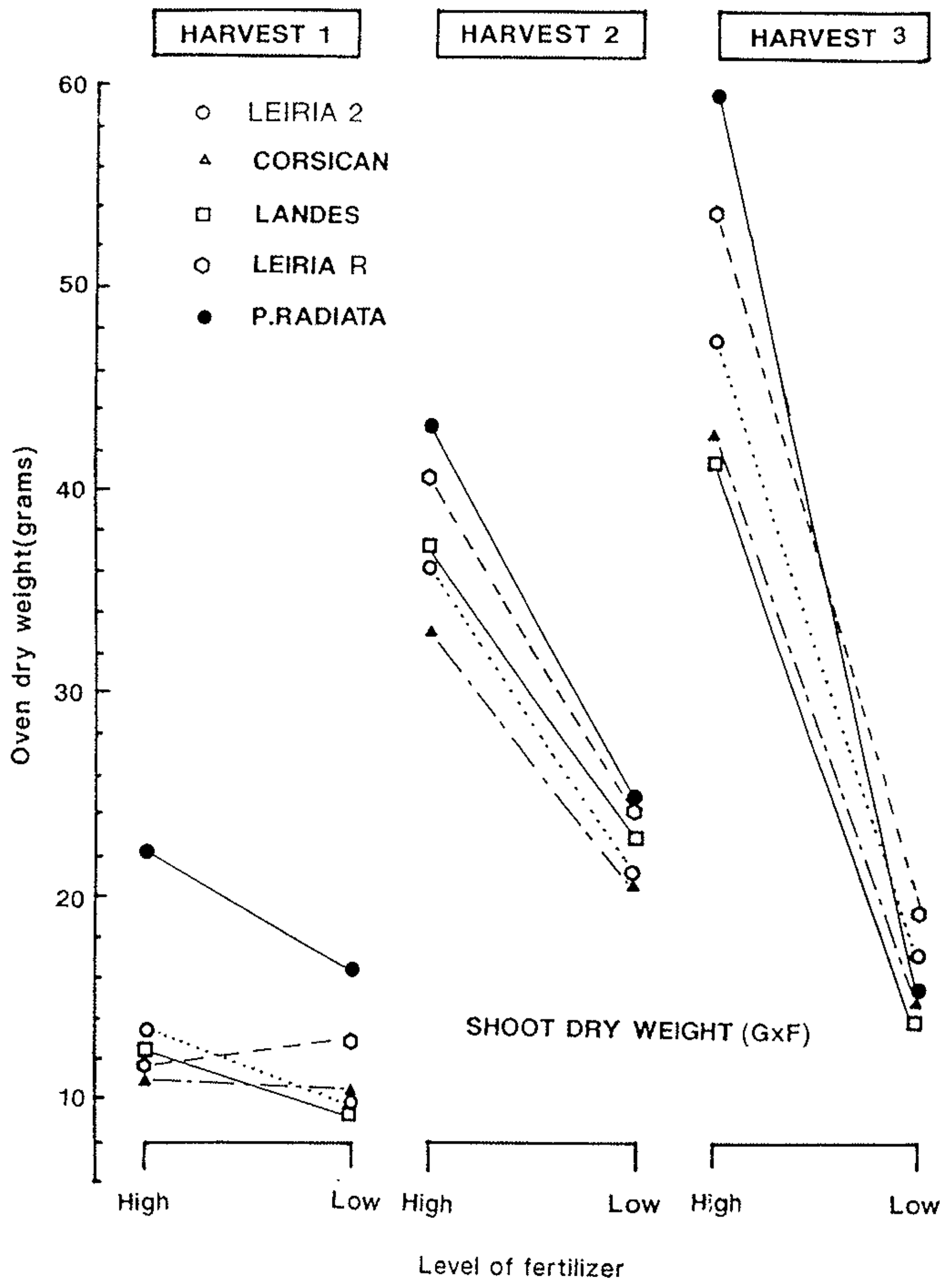

Figure 2.

Shoot dry weights in the seedling trial.

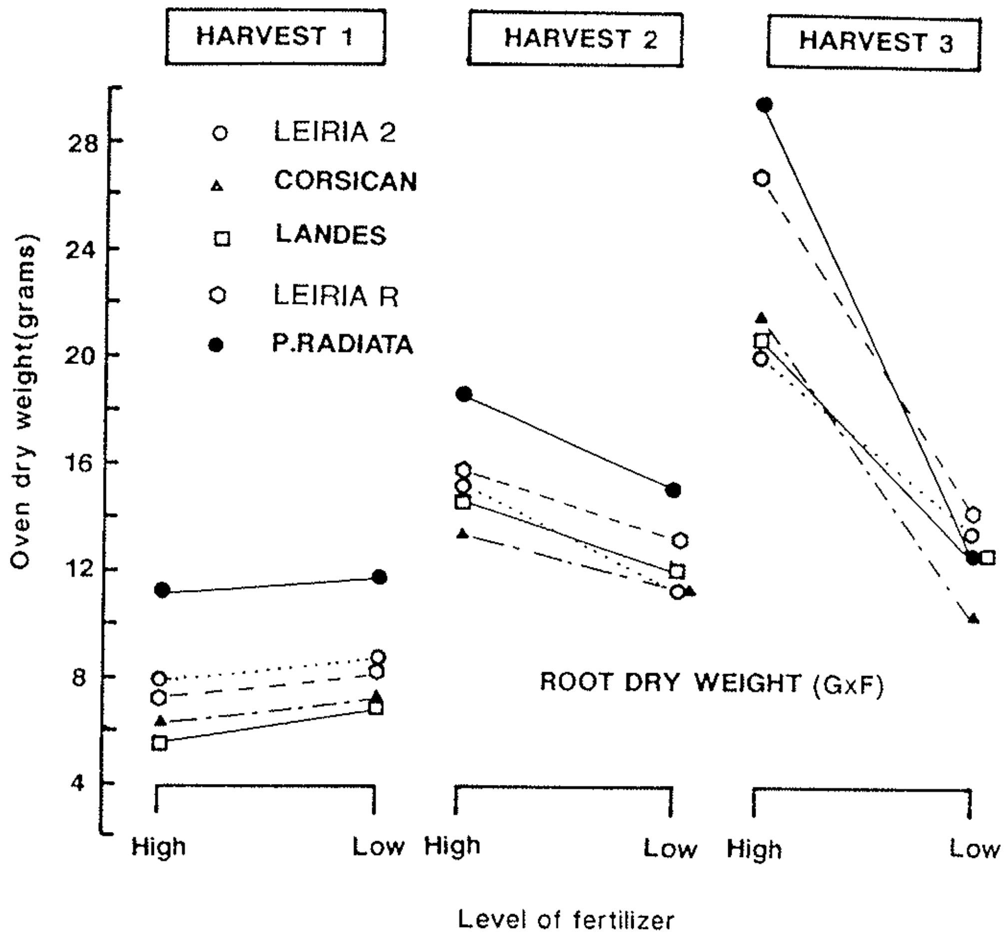

Figure 3.

Root dry weights in the seedling trial.

significant. Major differences in genotypes present were due to the greater dry weight of the *P. radiata* either with or without fertiliser.

Fertiliser addition significantly increased root dry weight over the three month treatment period. Genotype differences also related to the significantly higher dry weight production of *P. radiata* (Fig. 3).

Root/Shoot Ratio - Root/shoot ratios were significantly influenced by fertiliser additions but did not differ between genotypes (Table 1). Root production was relatively greater in the absence of fertiliser.

Table 1

Results from Harvest 1 for tissue dry weight and root/shoot ratio. Significance of the analysis of variance is included.

	Shoot Dry Wt.			Root Dry Wt. (g)			Root/Shoot Ratio*		
Source	Fertiliser		Geno-type	Fertiliser		Geno-type	Fertiliser		Geno-type
	F	NF		F	NF		F	NF	
Leiria2	13.4	10.2	11.8	7.8	8.8	8.3	.59	.85	.72
Corsica	10.8	10.3	10.5	6.4	7.3	6.9	.59	.73	.67
Landes	12.5	9.5	11.0	5.7	7.1	6.4	.47	.75	.61
LeiriaR	11.9	13.0	12.5	7.3	8.2	7.8	.62	.63	.62
Radiata	22.3	16.6	19.5	11.1	11.7	11.4	.49	.70	.60
Mean	14.2	11.9		7.7	8.6		.55	.73	
	Significance of the Variance Ratio								
Blocks		.001			.001			113	
Genotype		.001			.001			074	
Fertiliser		001			030			.001	
GxF		.012			987			045	
GxBlock1		.011			.018			.065	
FxBlock		.869			.726			.893	

* Data was transformed to angle arcsins for analysis.

Nitrogen Concentration - Fertiliser additions resulted in greater N absorption in both shoots and roots (Table 2). For the shoot mean values, *P. radiata* was significantly lower than the pinaster genotypes. There was no significant difference between genotypes for root N concentration.

INSERT FIGURES 2 AND 3 NEAR HERE

Nitrogen concentrations of root tissue were less than those in the shoots in all cases (Fig. 4).

Phosphorus Concentration - Fertiliser additions had no significant influence on P concentration of roots and shoots (Table 2). Genotype differences were significant. In the shoots, Landes had the highest P concentration which was similar to that of *P. radiata* and significantly higher than the P levels of the other pinaster genotypes. These latter did not differ significantly.

Table 2

Results from Harvest 1 for tissue nutrient contents.

Source	Nitrogen (% Dry Wt.)		Phosphorus (% Dry Wt.)		Potassium (% Dry Wt.)	
	Shoot	Root	Shoot	Root	Shoot	Root
			Genotype Means			
Leiria2	1.207	.734	.060	.079	.930	.487
Corsica	1.132	.829	.065	.096	1.067	.585
Landes	1.209	.771	.099	.075	1.164	.560
LeiriaR	1.156	.761	.074	.104	.913	.503
Radiata	.939	.709	.085	.063	.902	.426
			Fertiliser Means			
F	1.389	.907	.073	.078	1.031	.541
NF	.863	.614	.081	.088	.959	.484
			Significance of F			
Blocks	.020	391	.769	.143	.188	.016
Genotype	.001	.421	.007	.002	.001	.001
Fertiliser	.001	.001	.235	.097	.020	.003
GxF	.412	904	.179	.746	.601	.907
GxBlock	.224	.219	.840	.518	.362	.540
FxBlock	.519	.945	.374	.819	.671	.343

Leiria R had the highest concentration of phosphorus in the roots and this was significantly higher than that of other genotypes except Corsican.

Mean phosphorus concentrations were similar in roots and shoots (Fig. 5).

Potassium Concentration - Potassium concentration varied with both fertiliser addition and genotype (Table 2). Landes had the highest potassium concentration in the shoot with Corsican the next in order. The other genotypes did not differ and had significantly lower K concentrations than the Corsican genotype.

INSERT FIGURES 4, 5 AND 6 NEAR HERE

For root tissue the Landes and Corsican again had significantly higher K concentrations than Leiria R and Leiria 2. *P. radiata* had significantly lower K concentrations than the pinaster genotypes (Fig. 6).

Fertiliser addition resulted in considerable (.001 level) increases in tissue K concentrations with values for shoots approximately double those for roots.

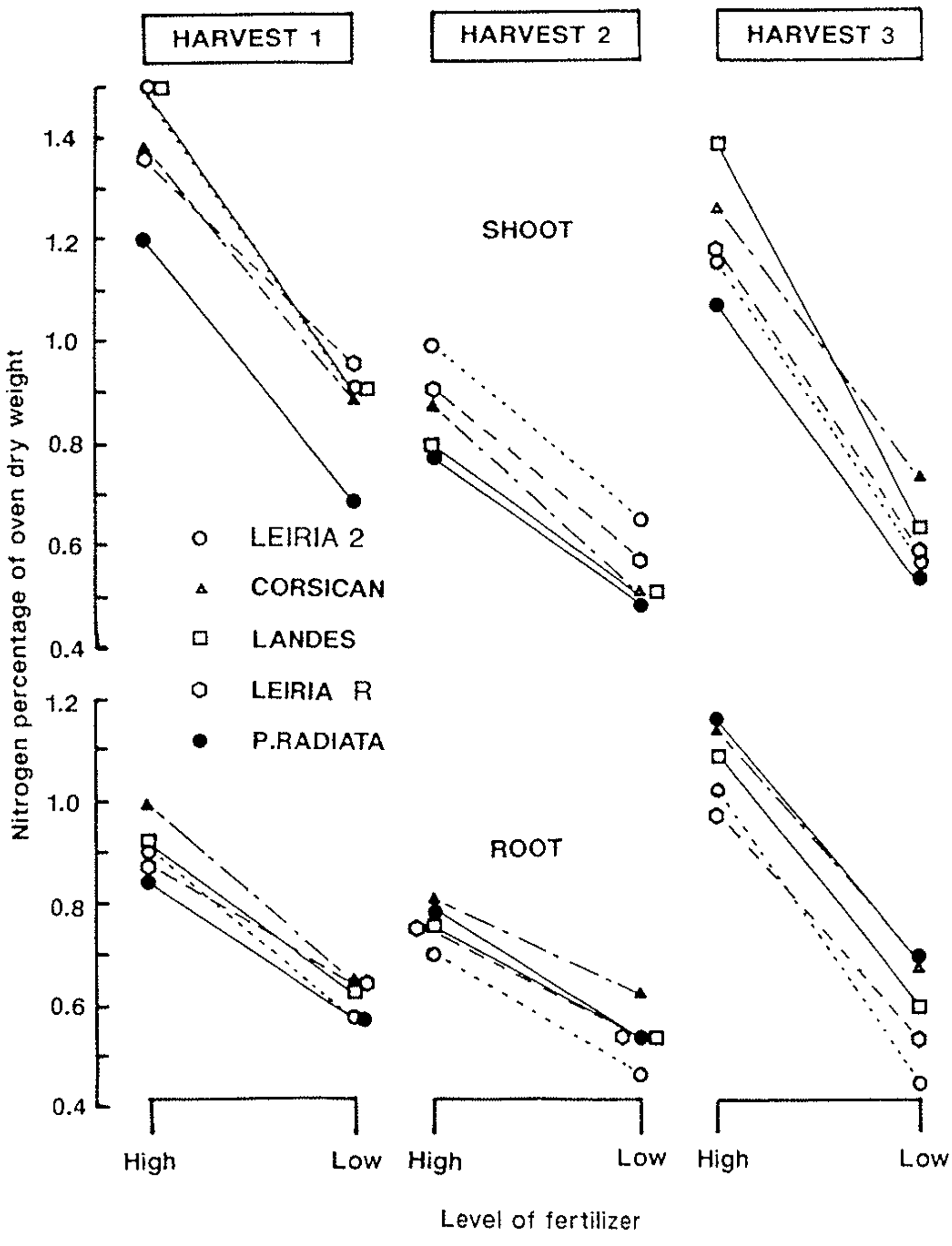

Figure 4.

Percentage of nitrogen in shoot and root dry weights, at each harvest.

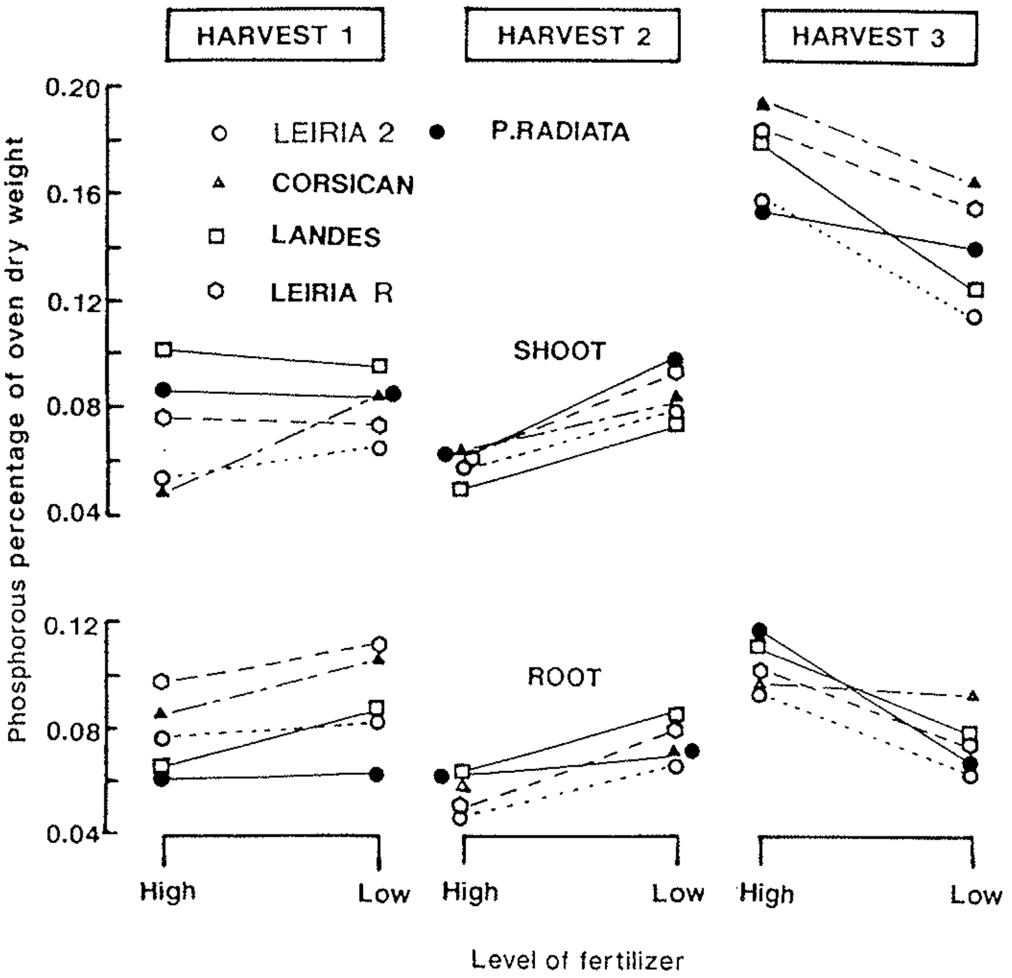

Figure 5.

Percentage of phosphorus in shoot and root dry weights, at each harvest.

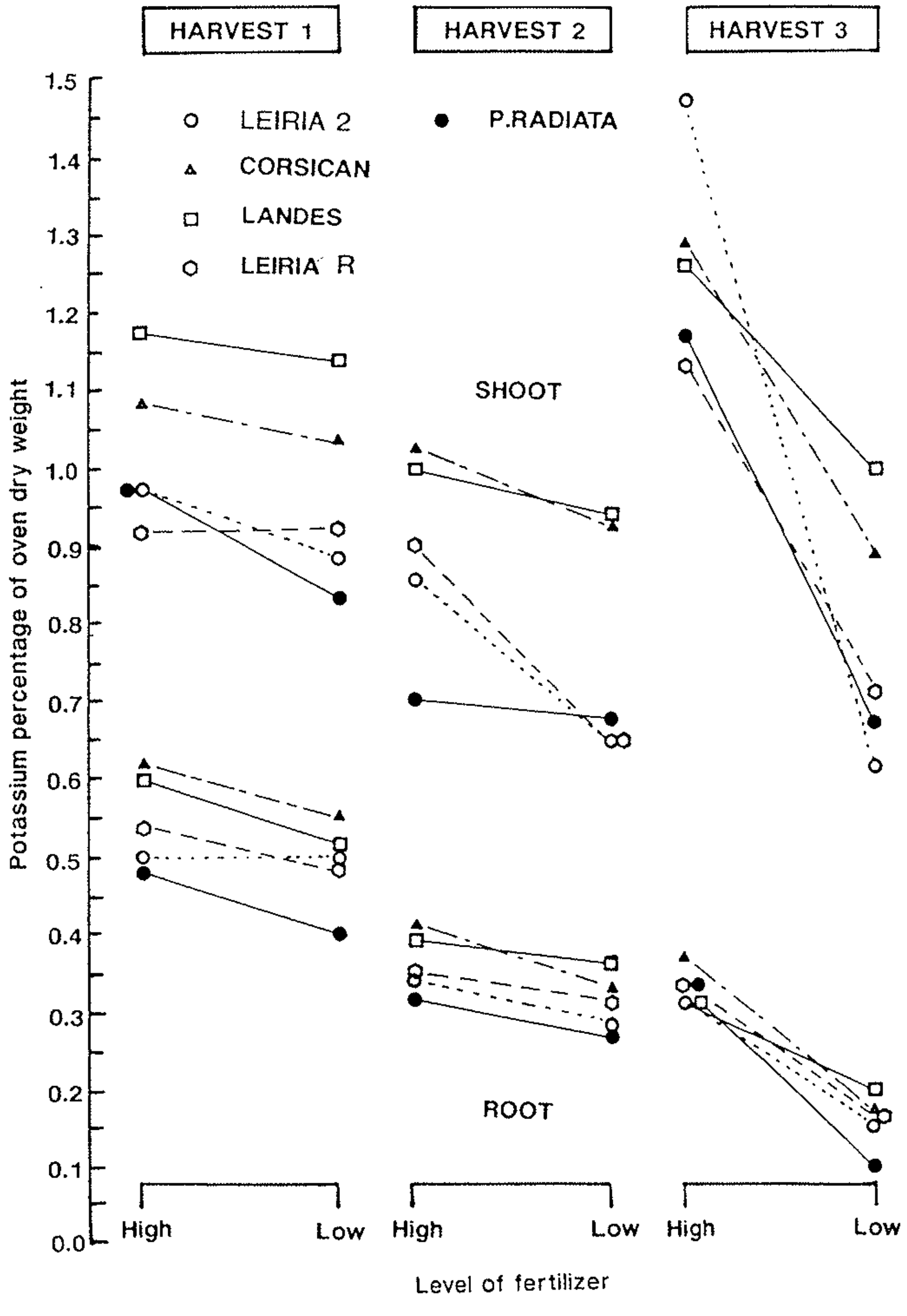

Figure 6.

Variation in potassium levels with provenance. Results are shown for roots and the shoots at each of three harvests.

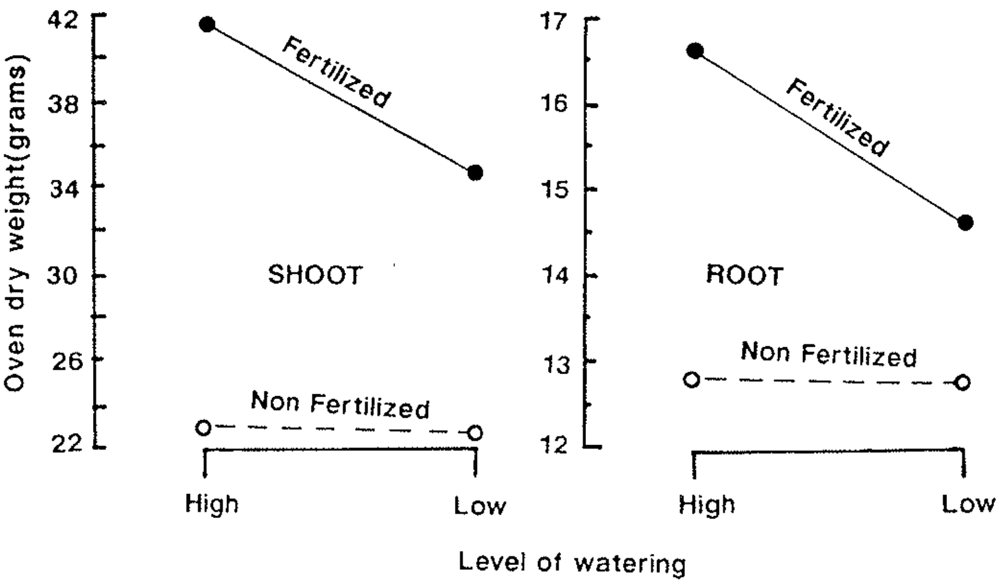

Figure 7

The nutrition by watering interaction in harvest 2.

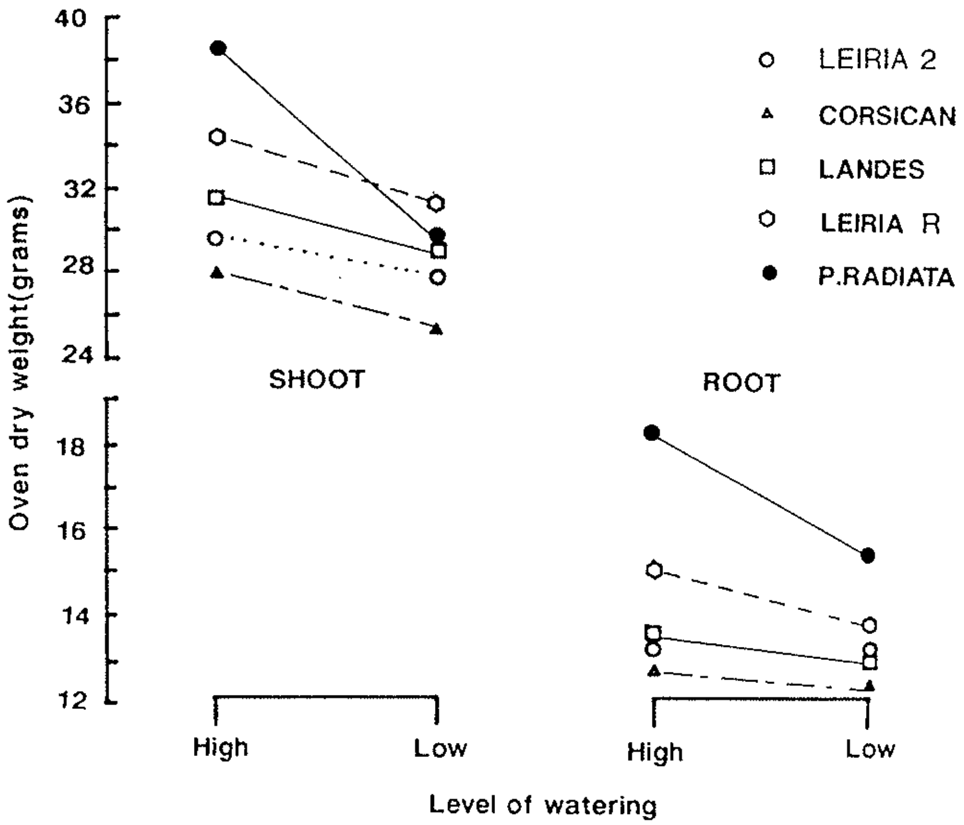

Figure 8.

The plant by watering interaction in harvest 2.

B. Harvest 2

Plants were 19 months of age with 7 months exposure to treatment at Harvest 2. This stage of the trial included treatments in which plants were droughted to the permanent wilting level prior to re-watering.

Plant Dry Weight - Fertiliser, genotype, watering and the fertiliser by watering interaction were significant for both root and shoot analyses (Table 3).

TABLE 3

Results for tissue dry weights in Harvest 2.

	Shoot Dry Wt. (g)					Root Dry Wt. (g)				
Source	Fertiliser		Watering		Genotype	Fertiliser		Watering		Genotype
	F	NF	HW	LW		F	NF	HW	LW	
Leiria2	36.2	21.4	29.7	27.9	28.8	15.2	11.5	13.3	13.3	13.3
Corsica	33.0	20.6	28.1	25.4	26.8	13.5	11.6	12.8	12.4	12.6
Landes	37.3	23.1	31.5	28.9	30.2	14.8	12.0	13.6	13.1	13.4
LeiriaR	40.7	24.3	34.2	30.9	32.6	15.8	13.2	15.1	13.9	14.5
Radiata	43.2	25.0	38.3	29.9	34.0	18.6	15.1	18.2	15.5	16.8
Mean	38.1	22.9	32.3	28.6		15.6	12.7	14.6	13.6	
Water	41.6	23.1				16.6	12.7			
Drought	34.6	22.6				14.6	12.7			

Significance of F

Source	Shoot	Root
Blocks	.0021	.074
Genotype	.001	.001
Fertiliser	.001	.001
Watering	.010	.043
GxF	.364	.767
GxW	.192	.399
FxW	.001*	.034*

* Not significant when analysed for pinaster plant groups only.

INSERT FIGURES 7 AND 8 NEAR HERE

The fertiliser by watering interaction (Fig. 7) resulted from a depressing effect of drought on dry weight production of fertilised plants but not of non fertilised plants. This interaction was significant only at the .034 level for root tissue and was removed, together with the significant watering effect, when the analysis was conducted for the pinaster genotypes only. In Figure 8 it can be seen in the non significant genotype by watering interaction that major depressions in dry weight, due to drought, are associated with the *P. radiata* genotype.

Analysis of root dry weights for the pinaster genotypes only, found no significance in differences between means for Leiria R, Leiria 2 and Landes genotypes and between Landes, Corsican and Leiria 2 genotypes (Table 3).

Root/Shoot Ratio - Analysis of root/shoot data (Table 4) provided results similar to those of Harvest 1, with only the fertiliser effect proving to be significant. The values in these older plants were lower than those in the first harvest indicating relatively greater shoot growth during this second stage of seedling growth in the 1964-65 summer.

Table 4

Results from Harvest 2 for root/shoot ratio, needle length and proportion of dormant buds.

	R/S Ratio			Needle Length(cm)			%Resting Buds		
Source	Fertiliser		Genotype	Fertiliser		Genotype	Fertiliser		Genotype
	F	NF		F	NF		F	NF	
Leiria2	.42	.54	.46	11.4	9.4	10.4	41	44	42
Corsica	.41	.56	.47	13.9	12.0	13.0	78	91	84
Landes	.40	.52	.44	13.6	12.4	13.0	72	91	81
LeiriaR	.39	.54	.45	11.7	10.4	11.0	31	59	45
Radiata	.43	.60	.49	11.2	8.8	10.0	0	0	0
Mean	.41	.55		12.3	10.6		45	58	
Watered		.45			11.6			50	
Drought		.48			11.3			53	
				Significance of F					
Blocks		.141			.354			.973	
Genotype		.074			.001			.001	
Fertiliser		.001			.001			.014	
Watering		.138			.272			.635	
GxF		.587			.596			.456	
GxW		.477			.836			.171	
FxW		.922			1.000			.117	

Needle Length - Genotype and fertilisation had a significant effect on needle length. Droughting did not influence needle length (Table 4).

Needle length increased with the addition of fertiliser and the Corsican and Landes genotypes had significantly larger needles than the other genotypes. Differences between Leiria R and Leiria 2 were not significant. *P. radiata* had the shortest needles.

Resting (Dormant) Buds - The number of dormant buds per treatment at time of harvest was expressed as a percentage of the total possible. Percentages were transformed to angle arcsins for analysis.

All buds in *P. radiata* were actively growing.

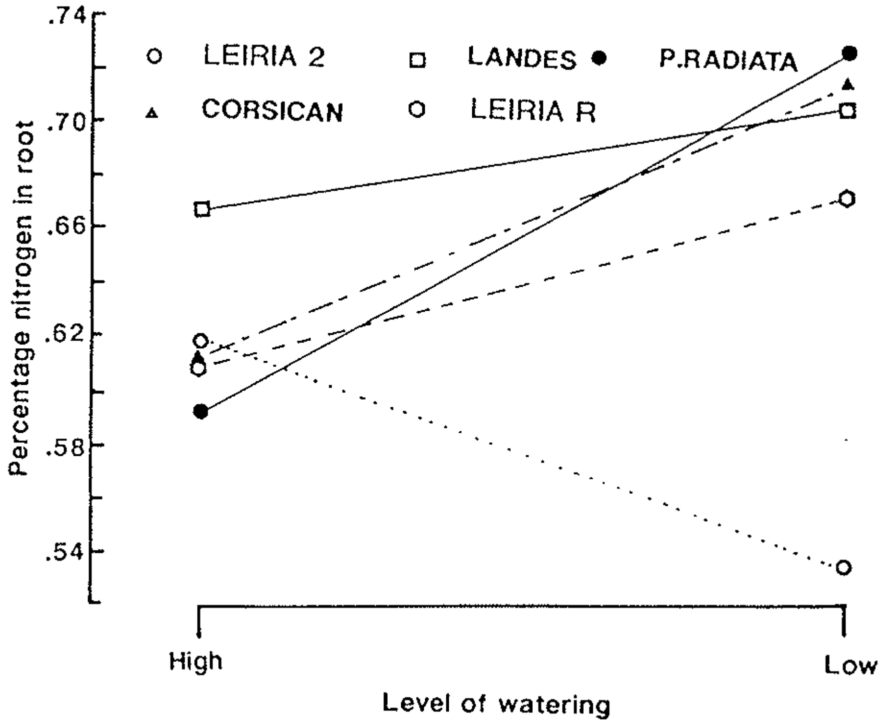

Figure 9.

Interaction between plant and watering for nitrogen content.

Significantly more dormant buds were found in the absence of fertiliser (Table 4) and no effect of droughting was measurable. The Landes and Corsican genotypes contained significantly more buds in the dormant condition than Leiria R and Leiria 2.

Nitrogen Concentration - For shoot tissue N concentration genotype, fertiliser and watering each had a significant influence (Table 5). The genotype by watering interaction was also significant in the analysis for root N.

In the root genotype by watering interaction, N tended to increase with drought effects with the exception of the Leiria 2 genotype (Fig. 9). This anomaly cannot be explained and probably represents experimental error.

Table 5

Results from Harvest 2 for tissue nutrient contents. Values are expressed as percentage of tissue dry weight.

Source	Nitrogen (%)		Phosphorus (%)		Potassium (%)	
	Shoot	Root	Shoot	Root	Shoot	Root
Genotype Means						
Leiria2	.813	.577	.068	.057	.751	.312
Corsica	.682	.661	.075	.066	.974	.370
Landes	.653	.685	.062	.076	.969	.375
LeiriaR	.748	.641	.076	.064	.770	.333
Radiata	.622	.659	.078	.066	.690	.294
Fertiliser Means						
F	.866	.756	.058	.056	.894	.362
NF	.539	.535	.085	.075	.768	.312
Watering Means						
HW	.671	.620	.071	.067	.824	.344
LW	.735	.671	.072	.065	.838	.330
Significance of F						
Blocks	.002	.279	.001	.004	.155	.001
Genotype	.001	.021	.009	.009	.001	.001
Fertiliser	.001	.001	.001	.001	.001	.001
Watering	.003	.016	.661	.588	.327	.129
GxF	.812	.204	.347	.270	.001	.514
GxW	.198	.017	.300	.349	.706	.532
FxW	.046	.204	.778	.149	.656	.874

Leiria 2 had the significantly highest N concentration for shoot data, and the lowest N concentration, by some considerable margin, in root tissue (Fig. 3).

INSERT FIGURE 9 NEAR HERE

For the shoot the N concentrations of Leiria 2 and Leiria 2 were not significantly different. Both were significantly higher than the other genotypes. For roots Leiria R N was significantly less than that of Landes. All other genotypes did not differ.

Droughting resulted in increased N concentration in both roots and shoots.

Phosphorus Concentration - Fertiliser and genotype had significant influences on shoot and root P. Watering had no effect (Table 5).

In the absence of fertilisers P concentration was significantly higher than with fertiliser additions and of the same level in both roots and shoots (Fig. 5). Shoot P in the Landes genotype was significantly less *P. radiata.* Other genotypes did not differ significantly in shoot P.

For root P, Landes was significantly higher than Leiria R and Leiria 2. The remaining genotypes did not differ significantly from either of these extreme values.

Potassium Concentration - Potassium concentrations in root and shoot tissue varied significantly with genotype and fertiliser main effects but not for watering (Table 5). The genotype by fertiliser interaction was significant for the shoot data and largely associated with exceptionally low values for *P. radiata* shoot K when fertilised (Fig. 6). The interaction remained (.05 level) when *P. radiata* was excluded from the analysis and would appear to result from relatively low values for Leiria R and Leiria 2, without fertiliser.

In root tissue, K concentrations for Corsica, Leiria R and Landes were highest and significantly different. to *P. radiata* but not to Leiria 2. Fertiliser addition increased the level of K in both shoot and root tissue.

Table 6

Results from Harvest 3 for tissue dry weight and root/shoot ratios.

	Shoot Dry Wt.(g)			Root Dry Wt.(g)			R/S Ratio		
Source	Fertiliser		Geno-type	Fertiliser		Geno-type	Fertiliser		Geno-type
	F	NF		F	NF		F	NF	
Leiria2	47.6	17.3	32.4	20.1	13.6	16.8	.42	.79	.52
Corsica	42.9	15.1	29.0	21.6	10.4	16.0	.50	.69	.55
Landes	41.4	14.1	27.7	20.8	12.1	16.5	.50	.86	.59
LeiriaR	53.8	19.5	36.6	26.8	14.5	20.6	.50	.74	.56
Radiata	59.5	15.4	37.4	29.7	12.8	21.2	.50	.83	.58
Mean	48.9	16.3		23.8	12.7		.49	.78	
				Significance of F					
Blocks	.026			.008			.415		
Genotype	.001			.001			.462		
Fertiliser	.001			.001			.001		
GxF	.026*			.004*			.507		

* Not significant in analysis of pinaster genotypes only.

As for Harvest 1, K concentrations in shoots were at least double those in the roots. Values were slightly lower than those recorded in Harvest 1.

C. HARVEST 3

Plants were 29 months old with 17 months exposure to fertiliser addition at time of Harvest 3. After Harvest 2, two plants were thinned from each pot by culling at ground level and shoot weights in Harvest 3 represent extended growth of two plants per pot only. Root dry weights still contained the remnants of the culled plants.

Plant Dry Weight - Significance was established for genotype, fertiliser and their interaction in both root and shoot data for dry weight (Table 6).

The significant interaction was removed in each case by excluding *P. radiata* from the analyses. It is believed that significance of the interaction was associated with relatively poor growth of this genotype in the absence of fertiliser (Figs. 2 and 3).

For the pinaster genotypes, Leiria R was significantly higher than Corsican and Landes but did not differ from Leiria 2 in shoot dry weight. It was significantly higher than the other three genotypes in root dry weight.

Fertiliser addition trebled shoot weight and doubled root weight.

Root/Shoot Ratio - As for the previous harvests only fertilisation had a significant effect on root/shoot ratio; shoots growing relatively better than the roots with fertiliser (Table 6).

Table 7

Results from Harvest 3 for needle length and shoot mortality per treatment.

Source	Needle Length (cm)			Shoot Mortality %		
	Fertiliser		Genotype	Fertiliser		Genotype
	F	NF		F	NF	
Leiria2	15.4	12.1	13.8	0.0	0.0	0.0
Corsica	14.5	12.9	13.7	6.2	6.2	6.2
Landes	13.9	12.1	13.0	25.0	37.5	31.2
LeiriaR	15.5	11.3	13.5	6.2	0.0	3.1
Radiata	12.8	9.6	11.3	50.0	43.7	46.9
Mean	14.5	11.6		17.5	17.5	
Significance of F						
Blocks		.046			.698	
Genotype		.001			.001	
Fertiliser		.001			.546	
GxF		.041			.681	
GxBlock		.922			.953	
FxBlock		.047			.159	

Needle Length - Needles had developed more of a mature appearance by Harvest 3 at which stage there was no significant difference in lengths between the pinaster genotypes

(Table 7). The needles of *P. radiata* were significantly shorter than those of the pinaster genotypes.

Fertilisation increased needle length.

Shoot Mortality - Percentages for shoot deaths at Harvest 3 were transformed to angle arcsin for analysis of variance.

Fertiliser addition had no effect on shoot health but genotype differences were significant at the .001 level (Table 7).

Greater mortality occurred in the *P. radiata* and Landes genotypes. The other pinaster genotypes had significantly less shoot damage and did not differ significantly between themselves.

Nitrogen Concentration - Significant differences in N concentration resulted from genotype and fertiliser in both root and shoot tissue (Table 8). The highest N concentrations in shoots were in the Landes and Corsican genotypes which were significantly higher than *P. radiata* but not Leiria 2 and Leiria R (Fig. 4).

Table 8

Results from Harvest 3 for tissue nutrient contents. Values are expressed as a percentage of tissue dry weight.

Source	Nitrogen (%)		Phosphorus (%)		Potassium (%)	
	Shoot	Root	Shoot	Root	Shoot	Root
			Genotype Means			
Leiria2	.859	.781	.136	.078	1.044	.226
Corsica	.993	.904	.180	.095	1.085	.270
Landes	1.019	.838	.151	.094	1.131	.257
LeiriaR	.875	.746	.168	.087	.918	.248
Radiata	.750	.919	.146	.091	.918	.222
			Fertiliser Means			
F	1.187	1.076	.173	.104	1.261	.331
NF	.607	.599	.140	.074	.778	.156
			Significance of the Variance Ratio			
Blocks	.931	.609	.014	.119	.003	.040
Genotype	.001	.002	.019	.113	.130	.465
Fertiliser	.001	.001	.001	.001	.001	.001
GxF	.181	.779	.664	.041*	.072	.291
GxBlock	.153	.749	.191	.750	.906	.551
FxBlock	.056	.916	.002	.402	.289	.637

* Not significant when analysed for pinaster plant groups only.

In root tissue the highest N concentrations were in *P. radiata*, Corsican and Landes. Leiria R had significantly lower concentrations than *P. radiata* and Leiria 2 had significantly lower N concentrations than Corsican and *P. radiata.*

Root and shoot N levels were comparable and almost doubled with fertilising.

Phosphorus Concentration - Treatment effects for shoot P concentration were significant (Table 8). Corsican values were significantly higher than Leiria 2 but not the other genotypes. For root tissue a significant genotype by fertiliser interaction was removed when *P. radiata* was excluded from the analysis (Fig. 5).

Phosphorus levels were significantly higher in the fertilised treatments.

Potassium Concentration - In both shoot and root tissue only the effect of fertiliser had an impact on K level (Table 8). Potassium levels were three to four times higher in shoot tissue than in root tissue and higher in fertilised than in non fertilised plants.

Discussion

Trial Design

The trial was designed to compare some juvenile attributes (growth rate, response to fertiliser and drought, needle length, root/shoot ratio, bud activity) of major *P. pinaster* provenances, that were not readily amenable to testing under field conditions.

The object was to evaluate similarities and differences between the pinaster genotypes over the early growing stage. The levels of fertiliser and droughting were imposed to allow comparison over an extreme range of conditions which influence the species in the field. Species response to fertiliser and drought per se was considered of secondary importance and hence these treatments were of simple, reliable application.

On a similar basis, *P. radiata* was incorporated in the trial as a control. It is a species well known to most workers in Mediterranean climates, it has a wealth of research literature directed to it and provides a scale on which to judge any variation between provenances. In all of these aspects the trial was successful in that significant effects for genotype, nutrition and droughting were obtained.

Three harvests were employed to sample variation associated with stages of seedling development. The stability of tissues and morphology during this early stage of rapid development and the sensibility of endeavouring to assign fixed, distinguishing features (i.e. height growth, needle length, fertiliser response) to provenances at this early developmental stage was questionable. Again, the staged harvesting procedure was successful in defining seedling variability. No attempt was made to analyse differences between harvests with statistical procedures.

Destremau *et al.* (1982) have recorded that for the Landes race, the young pine passes through several stages of development. Up to two years it possesses juvenile characteristics of rapid growth, short, fine needles, carmine coloured shoots, a significant number of 3 needled fascicles, smooth bark and a tendency to multinodal growth. From 2-6 years the pine enters a pre-puberty stage with longer, more supple needles, it loses the early, carmine colour of the spring shoot, regenerates less vigorously from cuttings or shoot damage and commences a better seasonal rhythm of growth in reaction to favourable conditions of the environment. After 6 years it commences to fruit but it is not until 18 years that full cone production is reached. At this age the needles are dense, long, plump, stiff and pointed. The current trial comparing plants from 15 to 29 months, samples the transition from juvenile to pre-puberty.

Detailed anatomical analysis of tissues was not incorporated, partly through the work involved but mainly due to the unsatisfactory yield associated with this avenue of investigation in the past (Fieschi 1932, Marsh 1939, Perry 1949). Developments of more useful genotype differentiating procedures by monoterpene (Bernard-Dagan *et al.* 1971) or isozyme analysis were beyond the scope of knowledge and facilities available at that time.

Species Comparisons

Comparative performance of dry weight production for plant groups (Figs. 2 and 3) clearly established the superiority of *P. radiata* to *P. pinaster* under conditions of high nutrition in the trial. This would be expected from a knowledge of performance of the two species under field conditions. Within the low nutrition treatment, however, an initial dry weight advantage expressed by *P. radiata* in Harvest 1 decreased at Harvest 2 and in Harvest 3 the *P. pinaster* provenances for Leiria exceeded *P. radiata*. Again, this may be expected from experience of the performance of the two species on infertile soils in Western Australia.

It is important that, at Harvest 3 when the low nutrient treatment was most pronounced, the genotype by fertiliser interaction was significant (.026 level) and attributable entirely to the *P. radiata* reaction. Removal of *P. radiata* data from the trial and re-analysis showed no significant interaction between genotype and fertiliser for the *P. pinaster* groups.

Other major differences measured between the two species were in the proportion of terminal buds in a dormant (resting) condition at Harvest 2 and the extent of shoot mortality at Harvest 3. Within the trial conditions these are considered to be intrinsic species differences representative of performance in the field.

Within the scope of this trial it is not possible to definitely state the cause of shoot mortality. Tip deaths were independent of soil fertility level and probably resulted from a combination of extreme insolation and restricted root moisture due to size of pots. Results revealed that under environmental stress significant differences between plant health are associated with different provenance sources in *P. pinaster*. A general superiority of this species over *P. radiata* was indicated for the conditions tested. Further, the provenances of maximum dry weight production (Leiria R and Leiria 2) were also amongst the most resistant to the disorder.

Little interpretation is offered for results obtained for chemical analysis of roots and shoots. Shoot nitrogen concentrations for *P. radiata* were consistently less than those of *P. pinaster* under both high and low nutrition treatments.

No clear pattern emerged between species for phosphorus concentrations. Shoot and root values of potassium for *P. radiata* tended to be the lowest of all plant groups and most similar to those of Leiria provenances.

Provenance Comparisons

Improved provenance comparisons were provided by removing the *P. radiata* data from analysis for root dry weight in Harvest 2 and shoot and root dry weight in Harvest 3.

Results from height development (Fig. 1) and shoot and root dry weight (Figs. 2 and 3) showed the Leiria R to be consistently greater in growth than the other three provenances. This superiority was present in all treatments in Harvest 2 (Table 3) and shown to be significant in Harvest 3 (Table 6). The greatest genotype similarity was between Leiria R and Leiria 2 and Corsican and Landes provenances, respectively.

It will be seen from the tables of results for each harvest and Figures 2 and 3 that, apart from the Leiria, the genotypes were reasonably similar over the variable conditions and period of the trial. Results for plant nitrogen (Fig. 4) contained no consistent pattern for provenances but tended to support the above trend for similarity between the pairs of provenances. Plant phosphorus concentrations (Fig. 5) were variable and not considered to be specific in provenance comparisons under conditions of the trial.

Results for potassium concentration (Fig. 6) showed clear differences between the provenances. The Leiria R and Leiria 2 plant groups were clearly the most similar in tissue potassium concentration. In Harvest 1 the Leiria R and Leiria 2 means did not differ significantly and were significantly different to the Corsican and Landes means which were similar (Table 2). The trend was consistent at each harvest (Tables 5 and 8) and suggests that provenance reactions to potassium in the environment are consistently different. These reactions may serve as a useful diagnostic tool under some circumstances and possibly are indicative of a variable response to applied potassium in the field. The similarity of K values for *P. radiata* and Leiria, could reflect dilution of a fixed amount of K, in the most rapidly growing plants.

Terminal bud development (Table 4) and shoot mortality (Table 7) indicate a continuous variation amongst provenances. Again the Leiria R and Leiria 2 and Corsican and Landes provenance pairs showed the greatest similarity. Although this trend was demonstrated in needle length comparisons in Harvest 2 (Table 4), results from Harvest 3 revealed (Table 7) that this attribute is not consistently suitable for comparing provenances in the seedling stage (Destremau *et al.* 1982).

Nutrient Concentration

Response of the separate pinaster genotypes to fertiliser was reasonably uniform and there is no sound reason to expect that fertiliser application is more relevant to one provenance than for the others. The variable potassium concentrations in the Leiria provenances may indicate that further field trials with potassium fertilisers with this provenance are warranted. Previous limited results for K fertilisers with the species in Western Australia (Hopkins 1960) most probably only relate to the Landes provenance which was most common in the earlier plantings. The data for *P. radiata* showed that responses to levels of fertiliser may vary between species.

The trial was designed simply to identify major differences in nitrogen, phosphorus and potassium concentrations of provenance groups and not to study physiological differences. With this in mind, the soil mix and the liquid fertiliser were ones that had been used for several years at Wanneroo for forcing *P. pinaster* stocks for grafting and in the after-care of grafts. There are no indications that they were not completely effective and safe. Plant phosphate concentrations may have differed at higher levels of added phosphorus (added fertiliser contained 23% nitrogen, 4% phosphorus and 10% potassium). This is not expected, however, as levels over the three harvests show a considerable range and expected adequacy of supply.

There was no significant relationship between the leading shoot disorder and level of nutrition and this supports the suggestion that the fertiliser program was adequate for healthy growth throughout the study. Low nutrient levels were significantly associated with an increase in the extent of shoot dormancy in Harvest 2.

Droughting

The single drought cycle to permanent wilting (PW) of the plants was monitored by daily measurements of pot water loss and the appearance of the plants each morning. Droughting commenced on February 18th 1965 and was terminated on March 18th, a period of 28 days. Over this period the average loss of the watered (HW) fertilised treatments in Block 2 (atmometer loss) was 210 ml per day. The first plant reached permanent wilting on the 13th day of droughting.

Pinus radiata and the fast growing Leiria genotypes reached permanent wilting earlier than the Corsican and Landes plants. This is shown in Table 9 by the atmometer loss associated with permanent wilting of each treatment. The interaction and fertiliser effects were not significant but the time for *P. radiata* to permanent wilting is significantly less than the *P.*

pinaster. *P. radiata* has larger plants and more drought susceptible shoots (Hopkins 1971b). There was no significant effect due to fertiliser and hence time elapsed to wilting is a function of tissue characteristics and not a simple function of plant size.

Leiria R and Leiria 2 wilted with significantly less atmometer exposure than the Corsican genotype (Hopkins 1971b).

Table 9

Water loss by treatments to permanent wilting (PW) and atmometer(control) loss to treatment permanent wilting.

Genotype	Fertiliser	Pot Loss to PW (ml)		Atmometer Loss (ml)	
		Treatment Mean	Genotype Mean	Treatment Mean	Genotype Mean
Leiria R	F	1109	1059	1611	1231
	NF	1101		852	
Leiria 2	F	1011	1067	1766	1337
	NF	1123		909	
Corsican	F	1103	1096	1666	2082
	NF	1088		2498	
Landes	F	1056	1091	1647	1678
	NF	1126		1712	
Radiata	F	946	984	476	529
	NF	1023		584	
Mean (ml)	F	1045		1432	
	NF	1074		1311	
Significance		NS		.01	

The amount of water transpired by each plant to permanent wilting was the same for all species (Table 9). As the pots contained equal soil weights and volumes and were watered to a constant pot capacity prior to commencing the droughting, it is reasonable to assume that the soil moisture potential at permanent wilting was similar in all cases.

Harvesting was not carried out until all plants had wilted and been re-watered, hence those that reached permanent wilting earliest (*P. radiata*, Leiria) had longer to recover from re-watering. There is no evidence from the genotype by watering interaction for dry weight (Fig. 8) that these differences had any influence on the pinaster results. The *P. radiata* results were most influenced by droughting (Fig. 9). This influence could also contribute to the significant fertiliser by watering interaction (Fig. 8) which did not apply to root dry weights when *P. radiata* was removed from the analysis.

The drought treatment was effective and again shows similarity between the Leiria R and Leiria 2 provenances in the time taken to reach permanent wilting. The Corsican genotype was the slowest to reach permanent wilting.

Drought resistance of *P. pinaster* provenances has been further compared by Hopkins (1971b) and supports the current performance to permanent wilting.

Root/Shoot Ratios

Roots were grown within confined containers and root/shoot ratios obtained cannot be confidently related to field conditions. In the trial there was no evidence of different ratios for genotypes. In all harvests, a highly significant effect of fertiliser indicated that root growth was relatively greater under low nutrient conditions for all genotypes.

The single droughting sequence had no discernible influence on root/shoot ratios.

Provenance Origin

Experience with Italian seed of *P. pinaster* (and that reputably from Lucca) in the past produced a slow growing, relatively short, flat topped pine. The current batch thought to be of Luccan origin (Leiria 2) behaved in the nursery and in field trials in a manner similar to that of Portuguese seed. A further batch of Italian seed included in the field trial has confirmed previous expectations for this provenance. The suggestion was that the Luccan seed batch could have been unexpectedly replaced by a Portuguese batch.

Sweet and Thulin (1963) identified a distinct fast growing, long needled provenance of *Pinus pinaster* from the Genova-La Spezia region of Italy in field trials in New Zealand. Such a provenance differing from the usual Italian tree was also suggested by Duff (1928) in his earlier studies of the species. The Valfreddana location could perhaps, have been within this group.

In the field trial associated with the present plant sources it has not been possible to separate the Leiria R and Leiria 2 groups on height, diameter and volume growth, after 21 years in the field. Pollen production, cone production and stem straightness were also significantly similar but significantly different (with volume) from the other provenances; including a further Italian provenance, in the trial (Hopkins and Butcher 1993). These similarities and the often close matches in the seedling study verifies that Leiria 2 provenance was derived from a Portuguese source.

The actual Luccan seed batch was included in a strip comparison trial in a following year. At age 22 years it has identical performances in flowering time, growth and form to the other Italian provenance (Hopkins and Butcher 1993).

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