IAWA Bulletin n.s., Vol. 12 (2), 1991: 195–206

VARIATION OF WOOD STRUCTURE AND PROPERTIES OF CUPRESSUS SEMPERVIRENS VAR. HORIZONTALIS IN NATURAL POPULATIONS IN GREECE

by

A.H. Paraskevopoulou[1]

Institute of Mediterranean Forest Ecosystems and Forest Products Technology, Terma Alkmanos, Ilissia, 115 28 Athens, Greece

Summary

The variation of specific gravity, ring width, tracheid length and tracheid cross-sectional dimensions was studied among the remote natural forests of *Cupressus sempervirens* var. *horizontalis* Gord. of the Greek islands Crete, Rhodes and Samos.

Analysis of variance indicated that the cypresses of Crete are different from the ones of Rhodes and Samos which are more similar. Cypress wood from Crete is characterised by greater tracheid length and ring width and lower density. In most of the studied traits the patterns of variation from pith to bark and from the base to the top of the tree are presented.

The potential of the cypress from Crete for genetic improvement of the studied traits is discussed.

Key words: Cupressus sempervirens var. *horizontalis* Gord., wood quality, specific gravity, ring width, tracheid size, genetic improvement.

Introduction

In Greece, the Mediterranean cypress (*Cupressus sempervirens* var. *horizontalis* Gord.) occurs in natural forests in the Aegean islands of Rhodes, Samos and mainly in Crete where it is a very important element of the vegetation.

Nowadays, the natural resources of this species are very limited but quite large areas over most of the country are covered by this species in the form of plantations, reafforestations, fire break zones and as windbreaks around orchards.

Bannister (1962) suggested that the geographical discontinuities between the cypress populations of these islands probably have operated as barriers to gene exchange for very many generations so that the evolution of each population could follow an independent course within the limits imposed by natural selection.

Because cypress is cultivated in plantations from ancient times onwards on sites which are unsuitable for agricultural cultivation, and produces wood of very good quality (Uzielli & Berti 1979; Tischler 1981; Papamichael & Paraskevopoulou 1982) used extensively in building constructions (chiefly as roofing poles), furniture, joinery, vine props, shipbuilding etc., it has been recommended for use in plantations of Greece instead of the fast growing exotics (Panetsos 1967). This has prompted the necessity to evaluate the potential of this species for genetic wood quality improvement. Information on the variation of wood quality traits and the identification of provenances of this species with desirable wood characteristics for necessary end uses throughout the natural habitat is therefore needed.

The most important wood quality characteristics: specific gravity, ring width, tracheid length and tracheid cross-sectional dimensions in latewood and earlywood were studied in the three natural remote populations of cypress on the Greek islands.

---

[1] The paper is partly based on a Doctoral dissertation defended by the author in the Institute of Botany, University of Athens, Greece.

The objectives of this study were:

1) The determination of the range of variation in the studied wood characteristics of the three remote provenances, between trees of the same provenance, and of different ages and height positions within the trees.
2) The evaluation of the main characteristics for improving the wood quality of cypress.

Materials and Methods

Ten trees were cut from each provenance. The parent rock of the three study areas of cypress is limestone. The elevation in Rhodes is 700 m, in Samos 230 m, and in Crete 1000 m above sea level. The soil in Crete is calcareous (pH 7.6, $CaCO_3 = 3\%$) and rich in organic matter. In Rhodes slightly acid to neutral (pH 6.3–6.9), clay, rich in organic matter and Ca^{2+}, Mg^{2+}, K^{+}. Finally, the soil in Samos is slightly acid with sufficient amounts of organic matter and Ca^{2+}, Mg^{2+} but poor in K. The results of the soil analysis are given by Papamichael and Paraskevopoulou (1982). The climate according to UNESCO-FAO 1963 classification is in Crete: dry season shorter mesomediterranean (biologically dry days $40 < x < 75$). In Samos: between dry season longer mesomediterranean (biologically dry days $75 < x < 100$) and dry season shorter mesomediterranean ($40 < x < 75$) and in Rhodes: dry season shorter thermomediterranean (biologically dry days $100 < x < 125$).

In each tree sample billets of 30 cm length were taken from four height levels, at 5%, 15%, 35% and 65% of the total tree height. Three discs adjacent to one another were sawn from each billet. The middle disc was used for taking samples for tracheid length and cross-sectional dimensions, the one below is for samples of specific gravity and the top one for reference. Two radii were randomly selected in each sample billet and along each radius samples 1 cm × 1 cm × 1 cm were sawn from pith to bark for specific gravity determination. In the annual rings representing time intervals of five years from the pith, the tracheid length and the cross-sectional dimensions of 45 tracheids were measured. All the sampled discs were sanded on the upper side, so that the growth rings were clearly visible for measurements.

The maximum moisture content method was used to determine specific gravity (Smith 1954). The specific gravity was calculated by the formula

$$G_r = \frac{1}{\dfrac{M_m - M_o}{M_o} + \dfrac{1}{1.53}}$$

where:

G_r = specific gravity based on green volume;
M_m = weight of saturated wood sample;
M_o = weight of oven-dried sample;
1.53 = average density of wood substance.

Samples for tracheid length measurements were macerated in a mixture of equal parts of 100% glacial acetic acid and 20 volume % of hydrogen peroxide in a 70°C oven for 48 hours (Franklin 1946). After maceration samples were washed with distilled water and the splinters were shaken gently in the distilled water until the individual tracheids of the wood were separated. From each sample ring 3 slides were prepared and 15 whole tracheids on each slide were measured. Each slide was projected on a Shadowmaster microprojector at a magnification × 30 and the tracheids were measured using a modified map measurer connected to an electronic tracheid length recorder.

Tracheid cross-sectional dimensions were measured on every fifth ring starting from the second ring from the pith. Along each selected radius strips 7–8 mm wide and 5 mm thickness were cut and polished until a smooth and evenly polished surface was produced suitable for microscopic examination. Each ring was divided into two halves representing in the broad sense the earlywood and latewood. A combination of five rows of tracheids and five tracheids per row in each sample was adopted. The rows of tracheids and the series of tracheids in each row were chosen at random. The measurements of tracheid cross-sectional dimensions was made by a Leitz Laborlux microscope fitted with a Leitz Ultropak incident light illuminator, a Leitz 12.5 × screw micrometer eyepiece and a 22 × objective.

For the analysis of the data the following statistical methods were used:

a) Analysis of variance (orthogonal and anorthogonal) by which the importance of the differences between provenances, trees in each provenance, height discs along the trunk of the tree, and annual rings or samples from pith to bark were assessed.
b) Variance component analysis by which the percentage of the total variation of each main factor studied and the interaction was assessed.
c) Simple regression analysis by which the degree of correlation of the features studied with age of the tree or height of the sample disc was assessed.
d) Multiple regression analysis by which the degree of correlation between tracheid length and age of the tree and height along the trunk of the tree was assessed.

Results

Specific gravity

Specific gravity based on provenance means ranged from 0.447 to 0.510 (Table 1) and individual tree values ranged from 0.396 to 0.594 (Table 2). Averaged over all trees specific gravity decreased across discs from the pith outwards (Fig. 1). There were no significant differences among the provenances of Rhodes and Samos but in trees from Crete specific gravity was significantly lower. All the provenances presented parallel patterns of variation from pith to bark (Fig. 3) and no relation between specific gravity and distance from the pith ($\tau = 0.09$–0.60) (Fig. 3).

Ring width

Ring width based on provenance means ranged from 1.74 mm to 3.29 mm (Table 1) and individual tree values ranged from 1.50 mm to 4.47 mm (Table 2). There were significant differences among the provenances; in Crete ring width was much higher. All the provenances presented parallel patterns of variation from pith to bark (Fig. 4). Averaged over all trees, ring width decreased across discs from the pith outwards (Fig. 5) and with height increased from the base (5%) to the third disc (35%) decreasing up to the top disc (65%) (Fig. 6).

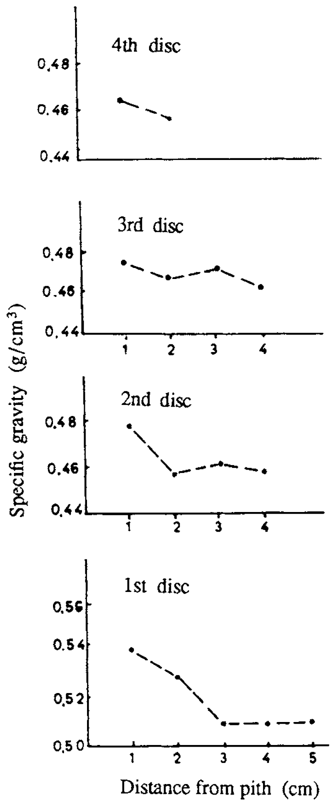

Fig. 1. Radial variation of specific gravity at four heights for *Cupressus sempervirens* based on 30 trees.

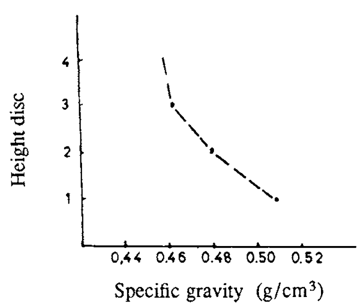

Fig. 2. Axial variation of specific gravity for *Cupressus sempervirens* based on 30 trees.

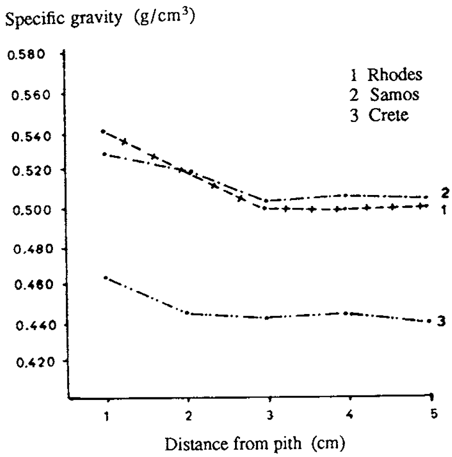

Fig. 3. Patterns of radial variation of specific gravity in the three provenances.

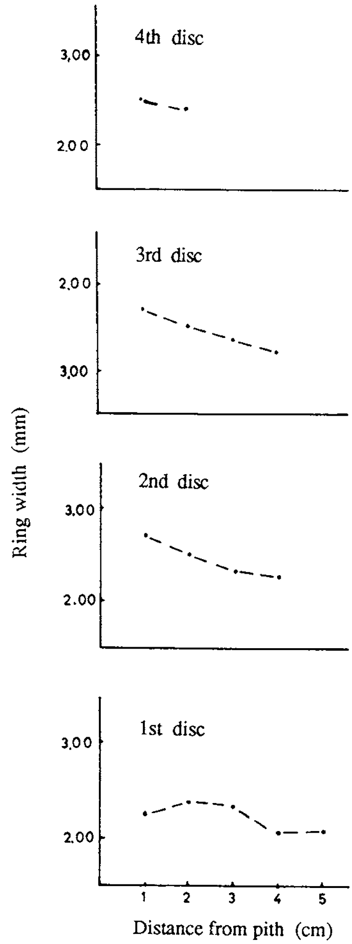

Fig. 5. Radial variation of ring width at four heights for *Cupressus sempervirens* based on 30 trees.

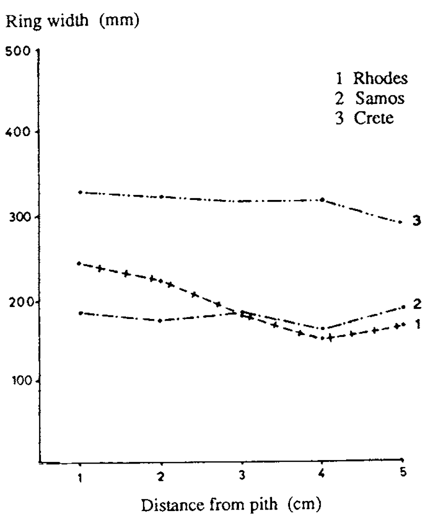

Fig. 4. Patterns of radial variation of ring width in the three provenances.

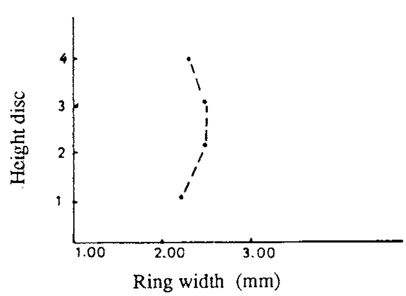

Fig. 6. Axial variation of ring width for *Cupressus sempervirens* based on 30 trees.

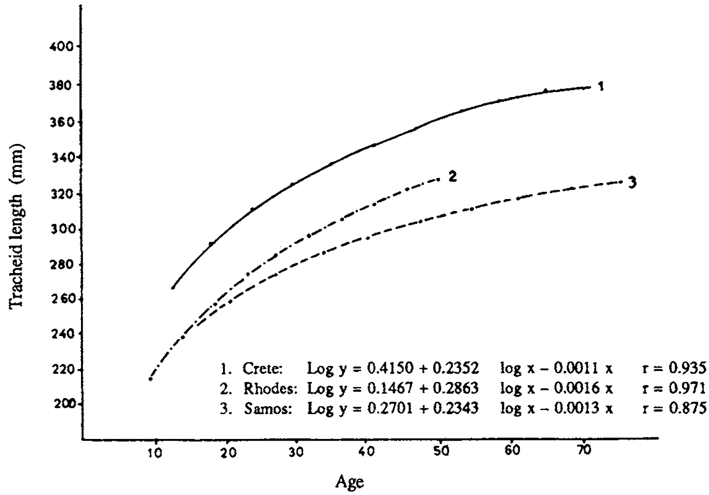

Fig. 7. Relationship between tracheid length and age of *Cupressus sempervirens* var. *horizontalis* wood in the three provenances.

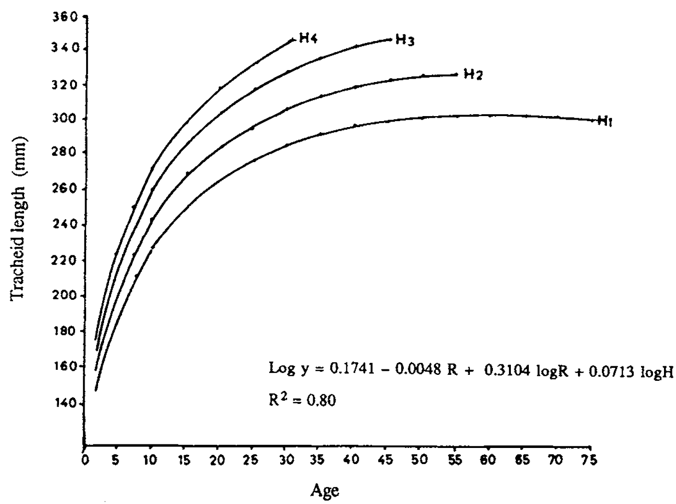

Fig. 8. Predicted relationships between tracheid length and ring number at the four height discs sampled of the Samos provenance.

Table 1. Mean provenance specific gravity, ring width, tracheid length and tracheid cross-sectional dimensions of *Cupressus sempervirens* var. *horizontalis*.

Wood characteristics	Range of tree means			VC %
	Crete	Rhodes	Samos	
Specific gravity (g/cm³)	0.447	0.509	0.510	23.0
Ring width (mm)	3.29	2.07	1.74	39.0
Tracheid length (mm)	2.92	2.63	2.56	7.26
Tracheid cross-sectional dimensions				
Earlywood				
Tracheid wall thickness (µm)				
radial	11.4	10.4	11.0	0.00
tangential	11.0	11.0	11.0	0.00
Tracheid diameter (µm)				
radial	60.8	66.0	68.7	6.0
tangential	59.1	61.0	62.7	0.0
Latewood				
Tracheid wall thickness (µm)				
radial	13.3	11.8	13.3	5.0
tangential	18.1	17.9	20.2	10.0
Tracheid diameter (µm)				
radial	37.6	32.2	37.0	0.0
tangential	54.7	50.9	54.8	0.0

Table 2. Range of tree means per provenance of specific gravity, ring width, tracheid length and tracheid cross-sectional dimensions of *Cupressus sempervirens* var. *horizontalis*.

Wood characteristics	Range of tree means			VC %
	Crete	Rhodes	Samos	
Specific gravity (g/cm³)	0.396–0.504	0.467–0.594	0.474–0.550	21.5
Ring width (mm)	2.50–4.46	1.50–2.52	1.42–2.08	10.3
Tracheid length (mm)	2.70–3.00	2.58–2.65	2.32–2.76	3.90
Tracheid cross-sectional dimensions				
Earlywood				
Tracheid wall thickness (µm)				
radial	10.0–13.2	9.1–11.0	9.4–11.9	45.2
tangential	10.1–11.6	9.9–11.8	9.9–12.1	27.3
Tracheid diameter (µm)				
radial	53.1–68.3	62.3–72.3	63.0–74.1	18.5
tangential	54.6–65.6	56.0–70.3	59.3–65.0	17.0
Latewood				
Tracheid wall thickness (µm)				
radial	12.1–14.6	10.4–12.9	10.7–14.8	48.1
tangential	17.3–20.2	15.8–19.7	18.8–21.1	16.4
Tracheid diameter (µm)				
radial	33.8–39.8	33.3–37.9	33.2–39.0	22.6
tangential	48.6–60.7	47.5–53.9	49.0–59.3	24.9

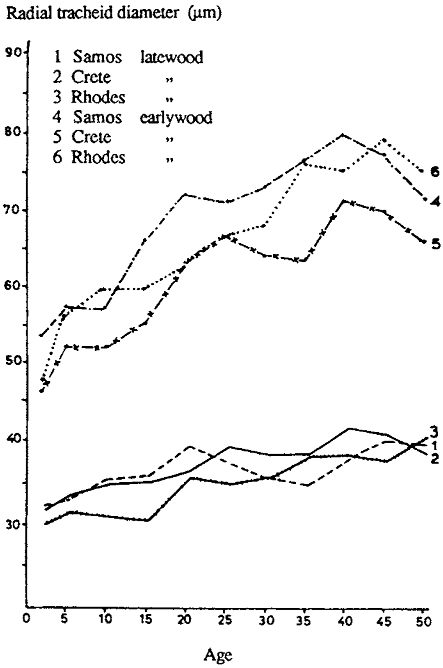

Fig. 9. Patterns of variation in radial tracheid diameter of earlywood and latewood to ring number from the pith in the three provenances.

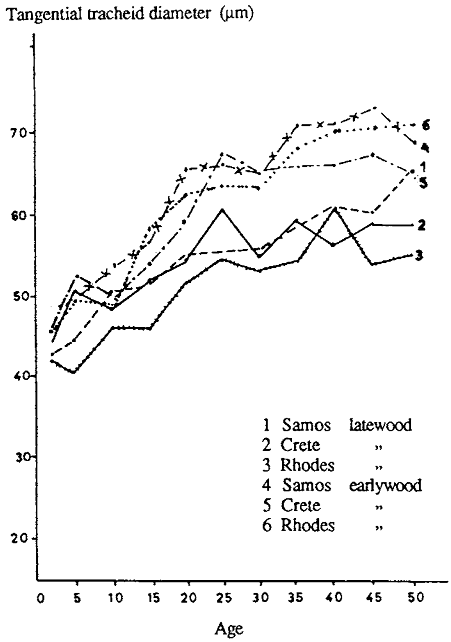

Fig. 10. Patterns of variation in tangential tracheid diameter of earlywood and latewood to ring number from the pith in the three provenances.

Tracheid length

Mean provenance tracheid length ranged from 2.56 mm to 2.92 mm (Table 1) with individual tree values ranging from 2.32 mm to 3.00 mm (Table 2). There were no significant differences in tracheid length among the provenances of Rhodes and Samos but in trees from Crete tracheid length was much higher (Fig. 7). Averaged over all trees, tracheid length increased from the pith outwards. The increase in average tracheid length across discs is common to many tree species (Dinwoodie 1961). The degree of dependance on age is stronger in the early age of the tree. The relationship between tracheid length and ring number from the pith was found statistically significant ($\tau = 0.87$–0.97) (Fig. 7). The relationship between tracheid length and tree height disc was found very poor ($\tau = 0.02$) although mean tracheid length decreased from the base of the tree up to 35% of the total tree height after which it decreases.

The axial and radial pattern of variation of tracheid length of cypress wood is described by the multiple regression model.

$$\text{Log } y = 0.1741 - 0.0048R + 0.3104 \log R + 0.0713 \log H$$

where:

R = ring number from pith, and
H = height disc along the trunk

by which a very considerable amount of variation (80%) of the tracheid length of cypress wood is explained (Fig. 8). The above relationship is very important for the prediction of the tracheid length at any age and height in the tree trunk.

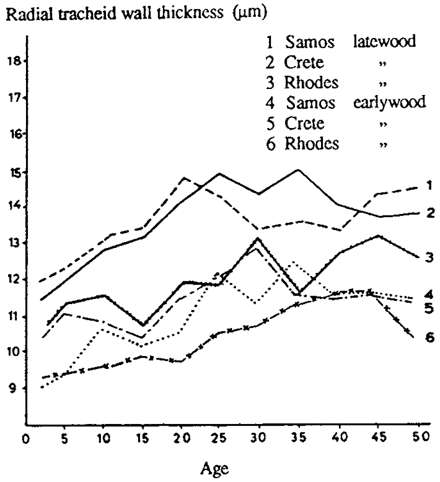

Fig. 11. Patterns of variation in radial tracheid wall thickness of earlywood and latewood to ring number from the pith in the three provenances.

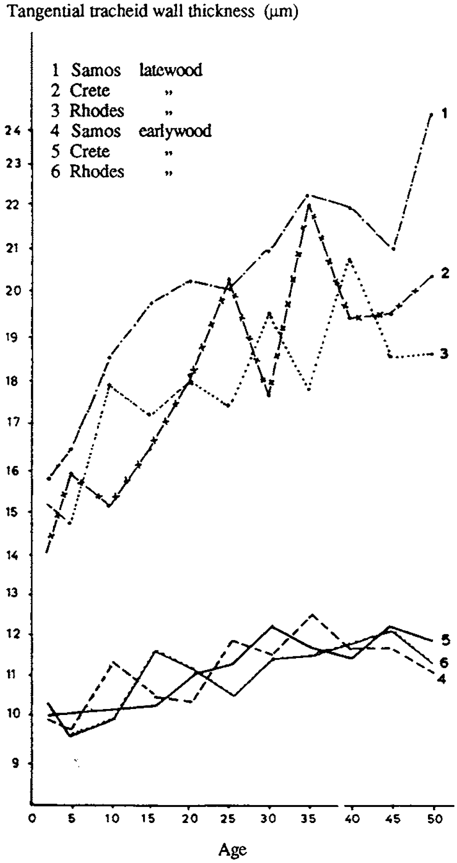

Fig. 12. Patterns of variation in tangential tracheid wall thickness of earlywood and latewood to ring number from the pith in the three provenances.

Tracheid cross-sectional dimensions

The provenance means for each of the tracheid cross-sectional dimensions in earlywood and latewood are presented in Table 1 and the range of the individual tree values of each provenance is presented in Table 2.

The patterns of variation of each of the tracheid cross-sectional dimensions with age in the three provenances is presented in Figures 9–12. The relationship of each of those with age is presented in Table 3.

Table 3. Correlation coefficients (τ) of earlywood and latewood tracheid cross-sectional dimensions with age in cypress wood.

Cross-sectional dimensions	r	
	earlywood	latewood
Radial tracheid wall thickness	0.21–0.50	0.34–0.52
Tangential tracheid wall thickness	0.41–0.52	0.50–0.71
Radial tracheid diameter	0.67–0.84	0.49–0.72
Tangential tracheid diameter	0.67–0.82	0.56–0.74

Discussion

There is not much information on the mean values of specific gravity, ring width and tracheid length and on the trends of variation along and across the stem of the studied traits of cypress wood. The mean values of specific gravity of the trees of this study are somewhat lower than those reported previously by Uzielli and Berti (1979) who refer to plantation material

In our material large variation was detected between the trees in all the wood characteristics studied with the exception of tracheid length. Those differences indicate an inherent potential from which an appreciable genetic gain perhaps could be achieved from breeding.

There are also considerable differences between the three provenances for specific gravity, ring width and tracheid length.

It is, however, impossible to assess how much of this individual provenance variation is due to environmental and how much to genetical factors (Thor 1964). The only certain way to differentiate between the variation due to heritability and that due to environmental effects is by testing the progeny of replicated controlled pollination crosses of the selected parent trees. This is a complicated and expensive undertaking and to assess wood properties certainly the progeny has to be grown beyond the juvenil stage, that is to twenty years or more.

A considerable number of investigations have shown that there is a decrease in specific gravity with increasing ring width and greater ring width is associated with shorter tracheid length (Panshin & De Zeeuw 1970).

The different climate of Crete may affect the growth of the trees resulting in greater ring width which in turn affects the wood specific gravity, but there is no explanation of the greater tracheid length, except that it may be due to an interaction of the effect of microenvironment and genetic factors.

Desirable values for specific gravity may be provided by either the Crete or the Rhodes and Samos trees since the preference for high or low specific gravity in a species depends on the desired end-use (Dadswell & Nicholls 1959; Nicholls *et al.* 1963). High-density wood is preferred for construction and furniture uses and it has generally been assumed to be preferable for pulping (Blair *et al.* 1975). If the main purpose is the conversion to sawn timber then high specific gravity will confer the best strength properties and high specific gravity should be the criterion when selecting for this feature. If the main purpose is the conversion to pulp then long tracheid length may be the most desirable wood characteristic since tracheid length is correlated with pulp strength properties (Dadswell & Wardrop 1959). In this case the superiority of trees of the Crete provenance is obvious. Generally speaking, a multi-purpose timber is that which would meet most of the current requirements.

In order to improve the productivity, growth habit and wood quality of cypress wood in Crete, where it is well suited, we should probably select trees on the basis of high tracheid length, ring width and average or above average specific gravity.

Conclusion

Evaluating the results of this study for wood quality improvement, the main conclusion drawn is that the provenance of Crete gives the highest tracheid length and annual growth and a reasonably high wood specific gravity and that trees from Crete thus have good potential for further improvement.

References

Bannister, M.H. 1962.Prospects for selection in the Cypresses.New Zeal. J. For. 8: 545–559.

Blair, R.L., B.J. Zobel & J.A. Barker. 1975. Predictions of gain in pulp yield and tear strength in young Loblolly Pine through genetic increases in wood density. Tappi 58 (1): 89–91.

Dadswell, H.E. 1958. Wood structure variations occurring during tree growth and their influence on wood properties. J. Inst. Wood Sci. 1: 2–23.

Dadswell, H.E. & J.W.P. Nicholls. 1959. Assessment of wood qualities for tree breeding. I. In Pinus elliottii var. elliottii from Queensland. Div. Forest Prod. Tech. Paper No. 4, CSIRO, Australia.

Dadswell, H.E. & A.B. Wardrop. 1959. Growing trees with wood properties desirable for paper manufacture. Appita: January 1959.

Dinwoodie, J.M. 1961. Tracheid and fibre length in timber. A Review of Literature. Forestry 34: 125–144.

Franklin, F.L. 1946. A rapid method for softening wood for microtome sectioning. Trop. Woods Yale Univ. Sch. For. 88: 35–36.

Nicholls, J.W.P., H.E. Dadswell & D.H. Perry. 1963. Assessment of wood qualities for tree breeding. Silvae Genetica 12: 105–110.

Panetsos, K. 1967. Inherited differences between populations and individuals of Cypressus sempervirens L. For. Res. Inst. No. 17.

Panshin, A.J. & C. de Zeeuw. 1970. Textbook of Wood Technology. Vol. I. McGraw-Hill, New York.

Papamichael, P. & A.H. Paraskevopoulou. 1982. Study of the physical properties of Cypress wood (Cupressus sempervirens var. horizontalis). Dasiki Erevna (Forest Research), Vol. 3 (1).

Smith, D.M. 1954. Maximum moisture content method for determining specific gravity of small wood samples. U.S. For. Ser. FPL, Rep. 2014 For. Prod. Lab., Madison, No.1.

Tischler, K. 1981. Physical and mechanical properties of Cypress timber. Division of Forestry, Scientific activities 1977–1980, Special publ. No. 200.

Thor, E. 1964. Variation in Virginia Pine. Part I: Natural variation in wood properties. J. For. 62: 258–262.

UNESCO-FAO. 1963. Carte bioclimatique de la zone méditerranéènne. Notice explicative, O.N.U., Paris.

Uzielli, E. & R.N.Berti. 1979. Aspetti tecnologici del legno di Cipresso (Cupressus sempervirens L.). In: Il cipresso: Malattie e Difesa (V. Grasso & P. Raddi, eds.): 95–109. Seminario CEE AGRIMED, Firenze.

APPENDIX

Table I – Summary of the analysis of variance for specific gravity of *Cupressus sempervirens* var. *horizontalis* wood from Crete, Rhodes, and Samos provenances.

	Sources of variation	DF	F	VC%
1	Provenances (S)	2	3.56	23.08
2	Plots / prov. (P/S)	3	3.93*	13.41
3	Trees / plot / prov. (T/P/S)	24	17.14***	21.58
4	Levels (L)	3	48.62***	12.26
5	Radii (Q)	120	3.79***	7.87
6	Samples (R)	4	33.89***	2.54
	Residual	743		19.36
	Total	899		