Results of a forest species trial in an Arboretum of North Greece

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Abstract

This study deals with the survival, growth and silvicultural characteristics of some exotic, Mediterranean and native species planted in the Vassilika Arboretum, North Greece (South Europe) under Mediterranean climatic conditions. The results obtained 25 years after trial establishment showed that, from the ten species planted only the native species *Pinus halepensis, Pinus brutia, Cupressus sempervirens* and to a lesser extent *Pinus pinea* and one east Mediterranean but not native in Greece *Cedrus libani*, managed to show a good result. The fast growing exotic species (*Pinus radiata, Eucalyptus globulus*) showed good growth in the early years, but a low survival rate after 25 years. Species outside of the floristic zone *Pinus nigra* and *Pinus sylvestris* presented very low growth and finally died due to harsh climatic conditions.

Key words: *Exotics, native species, Pinus, Mediterranean tree species, comparative plantation, Greece.*

1. Introduction

A common idea in several countries to cover the continuously increasing demands of wood consumption has been the expansion of forests and the introduction of exotic fast growing forest species (Kuusela, 1994; Malcolm, 1997). Many efforts have been made towards this solution world-wide; thus plantations have become increasingly important in supplying forest products throughout the world (Shepherd, 1986).

One of the main reasons for the wide use of exotics in reforestation is that they can be established easily on certain sites and have better growth rates than native species (Savill *et al.*, 1997). The single most widely exported tree species in the world is *Pinus radiata* D. Don (Smith *et al.*, 1997). In North Europe, the following exotic species are widely used for afforestation: *Pinus contorta* Douglas ex Loudon, *Picea sitchensis* (Bong.) Carriere, *Pseudotsuga menziesii* (Mirbel) Franco and *Larix leptolepis* (Siebold & Zucc.) Endl. (Kuusela, 1994; Savill *et al.*, 1997). In South Europe two Mediterranean Cedars from North Africa and Near East *Cedrus atlantica* (Endl.) Carriere and *Cedrus libani* A. Richard are used for afforestation for production and protection purposes. Among the exotics the most common are Eucalypts, in particular

Eucalyptus globulus Labill. in Portugal and Spain (FAO, 1981), Acacias and conifers such as *Pinus radiata* and *Pseudotsuga menziesii* (Oliveira, 1993).

Pinus radiata in some cases became the main species for commercial purposes because it exhibited high growth rates, short rotations and a great capability to adapt to different sites (Toro and Gessel, 1999). The widespread use of *Eucalyptus globulus* is due to that it is easy to be established, is generally of good stem form, grows fast, closes canopy rapidly, coppices vigorously and is wind-firm; furthermore it is characterized by the unpalatability of its juvenile leaves and it could be planted without fencing (FAO, 1981).

In Greece the use of exotics in afforestation is limited; the most common species used are *Pinus pinaster* Aiton, a west Mediterranean species not native in Greece, *Pinus radiata* and *Robinia pseudoacacia* L. (mainly in marginal lands). For the evolution of these plantations only a few data are available (Hatzistathis, 1979; Hatzistathis *et al.*, 1995). Among the native ones the most common species used are *Pinus brutia* Ten., *Pinus halepensis* Miller and *Pinus nigra* Arnold. The two mediterranean pines (*Pinus brutia* and *P. halepensis*) are usually planted for reclamation of burnt areas after wildfires.

At the same time, several problems have arisen from exotics world-wide planting; the most serious are: monoculture's ecological instability due to the decrease in biodiversity, damage by biotic and abiotic factors, negative impacts of pollutants, soil acidification, landscape modification, unification of management and changes in nutrient turnover (Dafis, 1990; Klimo, 1992). Thus introduction of exotics in many cases seems to be under revision and the criteria for non-indigenous species introduction are becoming more strict (Keufell and Krott, 1997).

Usually, the early plantations of exotic species tend to be established on sites of the above-average quality, leading to the over-estimation of their potential. Hence the desirability of species trials extended to testing sites of low fertility or harsh climate (Malcolm, 1997). Unfortunately and surprisingly, not so much attempt was made to assess the ecology of the exotics introduced from North America and other areas such as Australia and North Africa (Malcolm, 1997) and the knowledge about their monoculture is still insufficient (Ulrich, 1995). In many cases the introduction of exotics followed a pattern of initial establishment in gardens and arboreta and then if successful followed by vast scale planting after about half rotation later; these cases include *Picea sitchensis* in Britain and Ireland and *Pinus radiata* in New Zealand (Savill *et al.*, 1997). A significant effort to assess the ecology of exotics was made by the establishment of many forest arboreta all over the world, where different exotic and native species as well as species provenances were tried for their adaptation ability and silvicultural characteristics. The main goals of arboreta are: the comparison of different species, the study of species behaviour, the collection of information on (fast growing) exotic species adaptation, and the generation of information about plantation silviculture, management and policy (Chouinard and Vallee, 1976). Today, introductions are still taking place and there is still no substitute for extended trials before major planting schemes are started (Savill *et al.*, 1997).

The arboretum of Vassilika was established in 1970 following the above objectives. Different native and exotic forest species, mainly fast growing, were uniformly planted, in order to study the silvicultural characteristics, examine the adaptability of exotic species and compare them with the native ones, under the harsh site conditions which usually appear in the lower part of Greece (Dafis, 1973), and where the afforestations are mainly taking place (Hatzistathis and Dafis, 1989). The species studied were: *Pinus brutia, Pinus halepensis, Pinus pinea* L. and *Cupressus sempervirens* L., native species in Greece which thrive in the Mediterranean climate and appear in the *Quercetalia ilicis* floristic zone. *Pinus nigra* and *P. sylvestris*, which are also native but they thrive in much colder and wetter climate and in a higher altitude. *Cedrus libani* and *Pinus pinaster*, species of the Mediterranean basin but which do not appear in Greece; *Cedrus libani* is distributed only in the south-east Mediterranean coasts and *Pinus pinaster* in the West Mediterranean region. *Pinus radiata* and *Eucalyptus globulus* which are the most extensively used fast growing species for plantations worldwide and their origin is from California and Australia respectively.

This study presents the results obtained twenty five years after the Arboretum installation and deals with survival, growth rate and silvicultural characteristics of the species planted. The study brings species information in terms of survival, height, diameter, crown length and stem quality, and makes a comparison between the natives and exotics.

2. Materials and methods

2.1. Site description

The Arboretum of Vassilika is located at 25 km NE from Thessaloniki, North Greece. The altitude is 100 m asl. and the bedrock belongs to mesozoic limestones and schists covered by alluvials. The climate of the area is characterized Mediterranean based on the results of the nearest meteorological station of Loutra Thermi, 5 km far at the same altitude. The climate characteristics (period 1978-1995) are shown below:

Mean annual temperature	15.5 ^{0}C
Absolute maximum temperature	43 ^{0}C (July 1988)
Absolute minimum temperature	-12 ^{0}C (December 1980)
Mean maximum monthly temperature	31.7 ^{0}C (July)
Mean minimum monthly temperature	0.1 ^{0}C (January)
Mean annual humidity	69.5%
Mean annual rainfall	416 mm

The dry period lasts for over 5 months from May to the the first days of October, and this causes many problems to species survival and growth.

The vegetation of the area belongs to the class of *Quercetalia pubescentis*, alliance of *Ostryo-carpinion* and the association *Coccifero-carpinetum orientalis* (Dafis, 1973; Athanasiadis, 1986). The arboretum covers a total area of about three hectares and the plantations were accomplished in separate plots for each species, aiming at the creation of uniform stand conditions for each species and avoiding edge effect. The area is, in general, uniform, plain and with no streams or local wind effect; according to the results of soil sampling and analysis, the soil conditions of the arboretum do not differ spatially. No special treatment was applied (thinning, fertilization etc.) because the aim of the trial establishment was the evolution of the tested species under the natural process which usually happens in most plantations in Greece.

2.2. Methods

Ten species were planted in 1970 in hand made holes on 1.5m x 1.5m spacing, in a stand density of 4440 stems per hectare. Each species was planted in a separate plot of about the same size (~ 0.15 ha). The seedlings were 1+0 for all species except for *Pinus nigra* and *Pinus sylvestris* L. that were 1+1; they were supplied by the public Forest Nursery of Thessaloniki. Concerning the origin, the seeds of the native species (*Pinus brutia, P. halepensis, P. pinea, P. nigra, P. sylvestris* and *Cupressus sempervirens*) were from Greece, while the seeds of the exotic species (*Pinus radiata, P. pinaster, Cedrus libani* and *Eucalyptus globulus*) were supplied from France.

Measurements in three plots of 250 m^2 per species of all the survived trees were taken in 1978, at the age of 8 years after plantation, in 1988 and in 1995 (25 years old). The measurements concerned tree height using the Haga altimeter, diameter at breast height (DBH, in accuracy of 1 mm), crown length and stem classification according to the IUFRO system (Dafis, 1990; Clutter *et al.*, 1992; Tsitsoni, 2000). Note that, in the year 1978, where some individuals were shorter than 1.3 m in height (stems of the species *Pinus pinea, P. nigra, P. sylvestris* and *Cedrus libani*), the diameter measurements were carried out at 0.5 m above the ground.

For the estimation of soil physical and chemical properties of the arboretum area, ten soil profiles were taken, one in the center of each species plot. Soil sampling was taken every 10 cm until a depth of 50 cm; the samples were analyzed in the AUTH Laboratory of Silviculture for particle size distribution, organic matter content, nitrogen and pH (Brady and Weil, 1996).

Statistical analysis was performed at each age as well as for the final results using the SPSS package and the criterion Duncan was estimated for the comparison of means between the species. All survival percentages were transformed to arcsine square root values, before analysis (Norusis, 1994).

3. Results

3.1. Soil characteristics

According to the results of soil analysis the soil of the arboretum is characterized by a medium concentration of organic matter in the upper 10 cm of the ground (2.5-2.6 %), a medium concentration of total nitrogen, 0.16-0.17% and almost neutral acidity (pH 6.5-7.0). The soils are of CL (clay-loam) type and the nutrients show a reduction by depth (in 60 cm depth N is about 0.1% and organic matter 1%), and small differentiation of pH values. No spatial differentiation of soil characteristics was recorded.

3.2. Species survival

Data concerning species survival are shown in Figure 1, where two groups of species can be distinguished at the age of 8 years depending on survival rate, over or under 80%. The survival rate differs significantly between the two groups as it was revealed by ANOVA. After the year 1978 there was a decline in survival mainly for species belonging to the second group. The lowest rate reached 18% (in *Pinus nigra*) at the age of 18 years. In 1988 three species groups can be statistically distinguished for their survival: species with very low survival *Pinus nigra, P. sylvestris* and *Eucalyptus globulus* (survival rate under 30%), species with a medium survival *Pinus radiata, P. pinaster* and *P. pinea* (survival rate between 50-70%), and the other species with a high survival rate (over 80%).

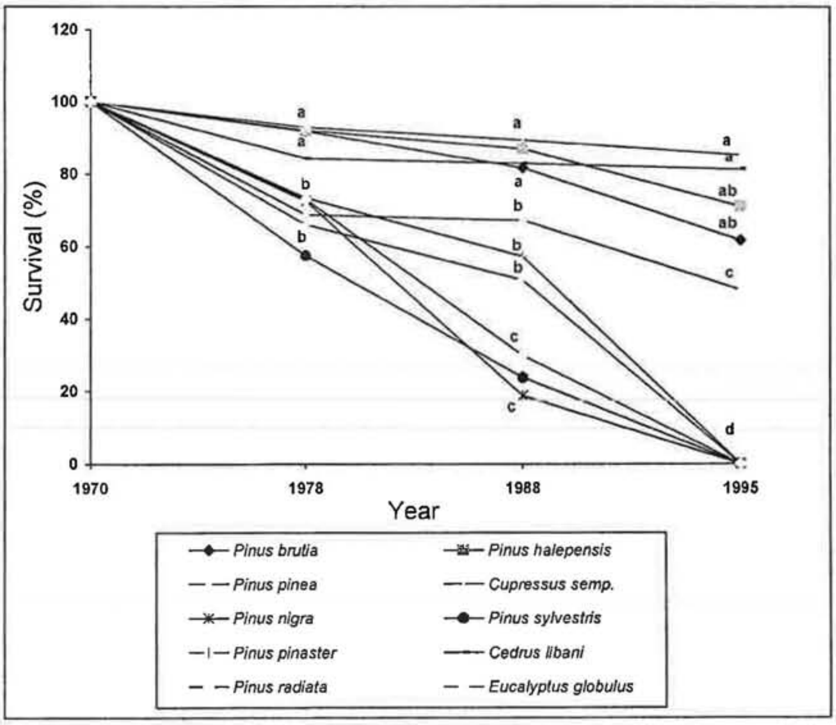

Figure 1. *Species survival (%) 25 years after their establishment. Values in the same year followed by the same letter are not significantly different at the 95% level of confidence (Duncan test).*

Analyzing the mortality of the species, that of the third group can be considered as regular mortality (Oliver and Larson, 1996), because it happened mainly in the suppressed or intermediate trees and the suppression and death can be considered as a natural result of stand development, playing the role of the thinning that should be done (Clutter *et al.*, 1992). While, in the second group some mortality can be considered as irregular mortality happening both in dominant and suppressed trees, and it is mainly due to the harsh site conditions (very long dry period, over 5 months during the summer and extremely high air temperatures). The mortality of the first group is very high and therefore it can be characterized as irregular mortality happening in all trees regardless of their crown class. This high mortality is obviously due to the harsh climatic conditions and especially due to the long dry period during the summer (5-6 months); the lack of any silvicultural treatment contributed to this high mortality too, especially to the most fast growing species (*Pinus radiata* and *Eucalyptus globulus*). It can be mentioned that in the year 1988, a great peak of air temperature was recorded during the summer months in the area, which is probably the reason for the death of many trees. The mean monthly maximum air temperature reached 35.7 ^{0}C in July, exceeding 4 ^{0}C the mean monthly maximum temperature (31.7 ^{0}C) of the last fifteen years, while the maximum values of air temperature were quite higher 5.6 ^{0}C (43 ^{0}C vs 37.4 ^{0}C). The mean monthly values this year were +1.1 ^{0}C reaching 30.7 ^{0}C in June, and +0.8 ^{0}C reaching 32.4 ^{0}C in August (in comparison with the average of the last fifteen years, 29.6 ^{0}C and 31.6 ^{0}C, respectively). These temperature differences (up to +5.6 ^{0}C), in combination with some increase in drought period during the second half of the eighties (from 5 to 6.2 months), are considered to be significant (Crawford, 1989) for species survival, thus species not well adapted to the climatic conditions of the area were strongly damaged.

Finally, some species failed to survive in the Arboretum 25 years after their establishment. These are the native species which are outside this vegetation zone *Pinus nigra* and *P. sylvestris*, the exotics *Eucalyptus globulus*, *Pinus radiata* and the West Mediterranean *Pinus pinaster*. The survived species were only the native species appropriate for this floristic zone (*Pinus brutia, P. halepensis, P. pinea* and *Cupressus sempervirens*) and one Mediterranean species, but not native in Greece, *Cedrus libani*, originating from the east side of Mediterranean basin. The best survival rate was found for *Cupressus sempervirens* (85.3%) and *Cedrus libani* (81.4%) followed by *P. halepensis* (71.0%) and *P. brutia* (61.7%); *P. pinea* presented the lowest survival rate (48.0%) in the group as it is the most light demanding species and the lack of any thinning strongly affected its crown development and vitality.

The exactly time of death fluctuated with environmental conditions mainly during the summer drought stress (Hatzistathis, 1979). Some symptoms were insect defoliations and diseases and finally many individuals died from these attacks in combination with the drought induced stress. Thus stem necrosis happened during or after the summer. Exotics even though presented a good evolution in the early years, afterwards their trees were weaken and lost their vitality. The very low stem quality and vitality was followed by many secondary insect attacks which in combination with the unfavorable climatic conditions caused extensive stem necrosis in the years 1987-90. For example, *Eucalyptus globulus* presented the highest growth in 1988 but stem quality was very low which in turn resulted in necrosis of all the individuals after a few years. The same was observed in *Pinus radiata* and *P. pinaster* stems which showed a high increment at the age of 18 years, but very low stem vitality; consequently, later heavy attacks by *Thaumetopoea pityocampa* in combination with insect attacks caused their necrosis. According to Markalas (1985), *Pinus radiata* tree tip necrosis occurred to a percentage of 65% because of

Thaumetopea pityocampa infestation, in Greece; on the contrary the native species *Pinus halepensis*, *P. brutia* and *P. nigra* were not infected.

The native species *Pinus sylvestris* and *P. nigra*, which natural distribution is outside this zone, presented a low increment and vitality throughout the time and gradually died. The survival percentage was 57.5% and 72.5% respectively, in 1978, and only 23.8% and 18.8% in 1988. *Pinus nigra* exhibited higher survival rate between the two species since it is more resistant to drought than *Pinus sylvestris* (Dafis, 1990); finally, no stems alive of both species were found in 1995.

3.3. Height

Table 1 shows the evolution of the mean height of the tested species. As it can be seen, the fast growing exotic species exhibited the higher mean annual height increment during the early years, until the year 1988. This year *Eucalyptus globulus* was the most productive species with a mean height of 9.18 m and a mean annual increment of 0.51 m, followed by the natives *Pinus halepensis* and *P. brutia* (0.47 m and 0.41 m respectively), and 0.40 m for *Pinus radiata*. *Pinus nigra* and *P. sylvestris* presented the lowest height (4.47 and 4.76 m correspondingly).

Table 1. *Height growth (± standard error) of the species tested in the Arboretum of Vassilika, North Greece*

	1978 (8 year)		1988 (18 year)		1995 (25 year)	
Species	Mean height (m)	Mean annual increment (m)	Mean height (m)	Mean annual increment (m)	Mean height (m)	Mean annual increment (m)
Pinus brutia	3.26±0.28c	0.41	8.42±0.25a	0.47	9.43±0.23a	0.38
Pinus halepensis	2.52±0.24d	0.31	7.32±0.24b	0.41	8.50±0.22b	0.34
Pinus pinea	1.21±0.14e	0.15	4.39±0.13d	0.24	5.98±0.11c	0.24
Cupressus sempervirens	2.33±0.20d	0.29	4.77±0.13d	0.27	6.21±0.10c	0.25
Pinus nigra	1.07±0.11e	0.13	4.47±0.16d	0.25	-	-
Pinus sylvestris	1.25±0.14e	0.16	4.76±0.14d	0.26	-	-
Pinus pinaster	3.10±0.25c	0.39	6.05±0.17c	0.34	-	-
Cedrus libani	1.34±0.12e	0.17	5.78±0.10c	0.32	8.44±0.13b	0.34
Pinus radiata	4.06±0.30b	0.51	7.17±0.20b	0.40	-	-
Eucalyptus globulus	5.11±0.31a	0.64	9.18±0.22a	0.51	-	-

* values in the same column followed by the same letter are not significantly different at the 95% level of confidence (Duncan test).

The species increased following the common sigmoid curve; they grew slowly during first years and then grew more rapidly. The height increment, at the age of 18 years, was almost equal to that at the age of 25 years for all species, while at the age of 8 years the increment was significantly lower for most species except for the fast growing species *Eucalyptus globulus* and *Pinus radiata*. These species exhibited the highest increment during the early years after planting reaching the peak point in 1978, when they had almost three to four times the height of the lowest species, presenting a mean annual increment of 0.64 and 0.51 m respectively and a mean height of 5.11 and 4.06 m versus 1.07 m for *Pinus nigra* and 1.21 m for *Pinus pinea*. Afterwards, their growth was gradually reduced. *Pinus brutia* and *P. halepensis* presented the higher mean annual increment at the age of 18 (0.47 m and 0.41 m respectively). *Pinus pinea* and *Cupressus sempervirens* had almost an equal increment throughout the time, while the increment of *Cedrus libani* improved over time (from 0.17 m in the first 8 years to 0.34 m at the age of 25 years).

Among the surviving species, *Pinus brutia* was the tallest (9.43 m) at the age of 25, followed by *P. halepensis* and *Cedrus libani* with 8.50 and 8.44 m respectively. *Cupressus sempervirens* and *P. pinea*, even though high survival rates, had a very low height increment reaching 6.21 m and 5.98 m, with a mean annual increment of 0.25 m and 0.24 m respectively. The low height of *Pinus pinea* was expected since this species is especially known on account of its slow juvenile growth (Oliveira, 1989). Results were subjected to ANOVA which revealed statistical differences between species height at all ages as it is shown in Table 1.

3.3. Diameter (DBH)

The diameter evolution of the species is shown in Table 2. The slow rate appeared until the age of 8-10 years and afterwards the trees grew faster; however, this is more evident in the species *P. halepensis and P. brutia*. The exotics exceed the native species from the early years and presented almost double diameter at the age of 8 years.

Table 2. *Mean diameter (±standard error) evolution of the species tested in the Arboretum of Vassilika, North Greece*

	1978 (8 year)		1988 (18 year)		1995 (25 year)	
Species	Mean diameter (cm)	Mean Annual increment (cm)	Mean diameter (cm)	Mean annual increment (cm)	Mean diameter (cm)	Mean annual increment (cm)
Pinus brutia	3.54±0.12c	0.44	12.17±0.50a	0.68	12.78±0.53a	0.51
Pinus halepensis	3.21±0.11c	0.40	11.76±0.57a	0.65	13.73±0.59a	0.55
Pinus pinea	1.78±0.04d	0.22	9.08±0.44c	0.50	10.54±0.50b	0.42
Cupressus sempervirens	3.22±0.09c	0.40	7.08±0.20^{e}	0.39	7.21±0.21c	0.29
Pinus nigra	1.62±0.08d	0.20	8.72±0.32cd	0.48	-	-
Pinus sylvestris	2.14±0.09d	0.27	8.10±0.38d	0.45	-	-
Pinus pinaster	4.60±0.17b	0.57	10.52±0.49b	0.58	-	-
Cedrus libani	1.92±0.08d	0.24	9.25±0.43c	0.51	12.97±0.36a	0.52
Pinus radiata	6.85±0.23a	0.86	12.15±0.59a	0.67	-	-
Eucalyptus globulus	6.10±0.21a	0.76	12.54±0.60a	0.70	-	-

* values in the same column followed by the same letter are not significantly different at the 95% level of confidence (Duncan test).

Eucalyptus globulus presented the higher diameter increment in 1988, reaching 12.54 cm at the age of 18 years (mean annual increment 0.70 cm) followed by *Pinus radiata* with a diameter of 12.15 cm and a 0.67 cm mean annual increment. The two native species, *Pinus brutia* and *P. halepensis*, followed with a diameter of 12.17 cm and 11.76 cm respectively.

As far as the survived species are concerned, the native species *Pinus halepensis* and *P. brutia* and the East Mediterranean *Cedrus libani* were the most productive with a diameter of 13.73 cm, 12.78 cm and 12.97 cm respectively (1995 measurements). The other native species presented significantly lower values, 10.54 cm for *Pinus pinea* and 7.21 cm for *Cupressus sempervirens*. Statistical analysis by ANOVA models revealed that there were no significant differences between the three species *Pinus halepensis, P. brutia* and *Cedrus libani*; statistically significant differences were found only between the three species and *Pinus pinea* and *Cupressus sempervirens* (Table 2). All the survived species had their best diameter increment at the age of 18 years, presenting a mean annual increment varying between 0.39 cm-0.70 cm, except for *Cedrus libani* which presented the same rate at the age of 18 and 25 years (mean annual increment 0.51 and 0.52 cm respectively).

3.4. Stem quality and crown length

Results of stem quality and crown length of the species that survived are presented in Table 3. At the age of 25 years, *Cedrus libani* had the shortest crown (4.33 m) and the best stem quality; 56.1% of stems are of high quality ('good' according to IUFRO classifications). *Cupressus sempervirens and Pinus pinea* presented a similar behavior having a mean crown length of 4.28 m and 4.58 m respectively and 39.2% and 40.1% of stem in good quality. *Pinus halepensis* had the longest crown (6.01 m) and the lowest stem quality. Only 13.3% of stems were of good quality; low stem quality is very common in this species (Dafis, 1987). *Pinus brutia* also showed bad tree quality having a high percentage (30.2%) of bad (twins or prone) stems and a low percentage (34.7%) of good quality stems, coupled with the second longer crown (5.22 m).

Table 3. *Mean crown length (±standard error) and stem quality (IUFRO classification) of species survived in the Arboretum of Vassilika, North Greece, 25 years after their establishment*

Survived species	Mean crown length (m)	Stem quality in 1995 (25 year) (%)		
		Bad	Medium	Good
Pinus brutia	5.22±0.23b	30.2	35.1	34.7
Pinus halepensis	6.01±0.20a	54.8	30.0	15.2
Pinus pinea	4.58±0.10c	19.6	40.3	40.1
Cupressus sempervirens	4.28±0.09c	20.4	40.4	39.2
Cedrus libani	4.33±0.30c	14.3	29.6	56.1

* values in the same column followed by the same letter are not significantly different at the 95% level of confidence (Duncan test).

Stems of *Cedrus libani, Cupressus sempervirens and Pinus pinea* exhibited a relatively good quality but they usually formed large branches with diameter over 5 cm, while stems of *Pinus halepensis* and *P. brutia* presented bad form (prone or twins). Statistical analysis revealed significant differences between the crown length of the species in the following order, *Pinus halepensis*, the longest crown, *P. brutia* with a medium crown length, and *P. pinea, Cupressus sempervirens* and *Cedrus libani* with the shortest crown.

4. Discussion

From the results obtained from this work it seems that the native species appropriate for the floristic zone of the study area thrive better in comparison with the other species studied (exotics or species that thrive in colder climatic conditions) if they are planted under similar climatic, edaphic and silvicultural conditions. This is probably due to the long term adaptation of each plant species to the ecological conditions of its natural geographical distribution; native species have the virtue of a long history of inherited adaptation to their environment (Smith *et al.*, 1997).

The failed species can be divided into two categories: (i) Native species from other vegetation zones that did not show good results (*Pinus nigra* and *Pinus sylvestris*). These species showed during the experiment the lowest growth in terms of diameter, height and stem quality characteristics. The main reason for their failure is probably the harsh climatic conditions of the area, since those species thrive in colder and wetter climate and they are less resistant to long periods of drought (Dafis, 1990). (ii) Exotic species that though a high growth rate in the early years (first twenty years), later failed, probably due to their higher demands of soil moisture, and especially due to the harsh climatic conditions of the study area (Dafis, 1990; Hatzistathis, 1979). This category includes the species *Pinus radiata* from California, *Eucalyptus globulus* from Australia and *Pinus pinaster* a West Mediterranean species not native in Greece.

High mortality was also recorded by Hatzistathis (1979) for the plantations of the exotics *Pinus radiata* and *P. pinaster* in North Greece while in the same region the native *Pinus nigra* presented better results. Hatzistathis and Zagas (1988) also found, that, in an experiment carried out in Greece, seedlings of the same exotic species (*P. radiata* and *P. pinaster*) presented iron deficiency (chlorosis) induced by high content of lime in the soil and high values of pH (>8) while the indigenous species *Pinus halepensis*, *P. brutia* and *Cupressus sempervirens* were normally growing.

Similar results also stated by Vidacovic and others (1990) for the same species in Croatia (South Europe) under similar climatic conditions. They found that *Pinus halepensis* and *Pinus brutia* were the most productive species versus *Pinus maritima (P. pinaster)* and *Pinus nigra* ssp. *dalmatica*. On the contrary, Panetsos and others (1985) found that some exotic species *Pinus contorta*, *Picea sitchensis*, *Pseudotsuga menziesii* and *Larix leptolepis* exceed the native ones (*Pinus sylvestris* and *P. nigra*) in a mountainous site of central Greece.

The growth of the tried species is really low; especially, the exotics presented much lower growth rates than that recorded for plantations in other countries such as in New Zealand and Australia (McMurtrie *et al.*, 1990; Maclaren *et al.*, 1995; Snowdon *et al.*, 1998), Chile (Toro and Gessel, 1999) and South Africa (Schoenau and Purnell, 1988; Grey, 1989). This is probably due to the harsh soil conditions, the diverse climatic conditions of the area, the annual distribution of precipitation which in turn gives a long dry period during the vegetative period, and the lack of any silvicultural treatment. In comparison with the available data from plantations of the same species in North Greece, the growth of the native species is similar to that found in some plantations (Hatzistathis, 1979; Hatzistathis *et al.*, 1995). Oliveira (1989) also, recorded a similar height (4.71-6.13m) for *Pinus pinea* plantations in Portugal but much higher mean diameter (17.5-21.0 cm) at the age of 28 years.

In conclusion, it can be said that the tried native species *Pinus halepensis, Pinus brutia, Pinus pinea* and *Cupressus sempervirens* seem to present, in these site conditions, better results than that of the fast growing exotic species *Eucalyptus globulus* and *Pinus radiata*, in a long-term basis. The latest are considered to be the highest wood producing species and their use is usually preferred in afforestation in Mediterranean region (Oliveira, 1993). This is true, but only where the appropriate soil and climatic conditions prevail. Additionally, species that consume high quantities of water such as the fast-growing exotics are inappropriate for the most sites in Greece (Hatzistathis and Dafis, 1989).

Finally, the results obtained can be taken into account in the reforestation plans of similar sites of the Mediterranean region leading forward to a more wide use of the native species. Furthermore, in such sites, afforestation usually plays an important role to recreation and soil protection, so the use of the non-familiar exotics modifies the Mediterranean landscape where the Mediterranean pines (*Pinus halepensis, Pinus brutia, Pinus pinea)* and *Cupressus sempervirens* dominate, presenting high ecological and aesthetic values (Piussi, 1992; Tsitsoni, 1997). On the contrary, the use of the native species could contribute to the maintenance of the beauty of Mediterranean landscape.

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