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CONSTANTINOS P. PANETSOS

MONOGRAPH OF ABIES CEPHALONICA LOUDON
MONOGRAFIJA ABIES CEPHALONICA LOUDON
MONOGRAPHIE D'ABIES CEPHALONICA LOUDON

ARAVANOPOULOS

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Constantinos P. Panetsos

MONOGRAPH OF *ABIES CEPHALONICA* LOUDON

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1. INTRODUCTION

Abies cephalonica was first identified and described as a new species of the genus *Abies* by J. C. Loudon in 1838. The material upon which Loudon made his original description was collected from the largest Ionian island, Cephalonia (Cephallenia), so the derivation of the specific epithet. Its seeds were first collected and sent to England for raising seedlings in 1824, by General C. J. Napier, governor of the island at that time. (Samios 1908). In the literature the species appears with a number of common names such as, Greek fir, Grecian fir, Mount Enos fir, Cephalonian fir, etc. Its common name in Greece today, is Cephalleniake elate (Κεφαλληνιακή ἐλάτη).

According to Theophrastus *Abies cephalonica* was an important species at his time, as it is today, forming valuable lumber producing stands in southern Greece and especially in Peloponnesus. It grows mostly in pure stands of considerable extent or becomes mixed with *Pinus nigra* Arn.

The natural distribution of the species is not clear and well defined, since north of Mount Oxya (Lat. 38° 50′ N) there occur populations of fir which Mattfeld (1927, 1930) considered as products of an ancient hybridization between *Abies cephalonica* and *A. alba* Mill., the European silver fir, which extends southward to the northern boundaries of Greece to Yugoslavia (Lat. 41° 5′ N). The area between the ranges of the above two species is occupied by intermediate forms which Mattfeld collectively designated as *A. × borisii regis*. According to the same author these forms at their northern limits more closely resemble *A. alba* and grow with trees typical of that species and at the southern limits of distribution resemble and associate with typical *A. cephalonica*.

Recent investigations, however, show that hybrid forms, as described by M a t t f e l d, occur even further south in Peloponnesus fir populations. (B a s s i o t i s 1956, P a n a g i o t i d i s 1965).

These types, found in central Greece as well as in parts of northern Greece and in the Rodope Mountains of Bulgaria were cited by S t e b b i n s (1950) as evidence for the »origin of a new race through hybridization«. Furthermore, he states that all three species i. e. *A. alba, A. cephalonica* and their hybrids *A.* × *borisii regis* should be taxonomically treated as races of a single polytypic species.

A number of botanists have recognized and described different species within the area where typical *Abies cephalonica* occurs, such as *A. panachaica* Heldr. and *A. reginae Amaliae* Heldr. in Peloponnesus, *A. apollinis* Link on Mount Parnassus of southern central Greece. Recently, L i u (1971) in his monograph of the genus Abies classified *A. apollinis* Link as *A. cephalonica* var. *graeca* (Fraas) Liu nov. comb. together with *A. equi-trojani* Aschers et Sint., growing on the Mountain Ida (Kaz-Dagh) in the northwest of Asiatic Turkey. M a t t f e l d (1927), who visited the area where the above cited species occur, states that he could not find any differences between these species and the typical *A. cephalonica* growing on Mount Aenos of Chephalonia island.

Common environment experiments carried out by the present author, as well as study of a number of morphological and anatomical characters of threes growing in almost all the fir populations occuring in Greece, do not justify recognition of species or varieties within the range of typical *Abies cephalonica*. As far as *A. equi-trojani* is concerned, there is no resemblance with fir growing on the Mountain Parnassus. There is, however, as it will be presented in another publication, considerable affinity between this species and the fir population growing on Athos peninsula of Chalkidiki.

Figure 1 gives the distribution of fir forest in Greece as it appears on the forest map of Greece with some adjustments applied by the author, based on personal observations and the Greek literature (K o s s e n a k i s 1947, M o u l o p o u l o s 1951, P a p a i o a n n o u 1952). The distribution of species and hybrids is presented in Figure 2 as appeared in the literature. Altitudinal distribution is generally betweeen 400 and 1800 m. and very rarely up to 2000 m. or more. The optimum is considered to be from 800 m. to 1200 m.

Through its range greek fir may be found growing on soils derived from a variety of parent materials such as limestone, dolomites, shale, serpentine, sandystone, mica-schist and argillic-schist, with pH ranging from 5 to 8 (B a s s i o t i s 1956). Considering this wide tolerance, one might expect the species to contain a large genetic variability and relatively slight development of site adapted local races.

The most productive sites are well-drained deep soils, having abundant but not excessive moisture (A l e x a n d r i s 1969).

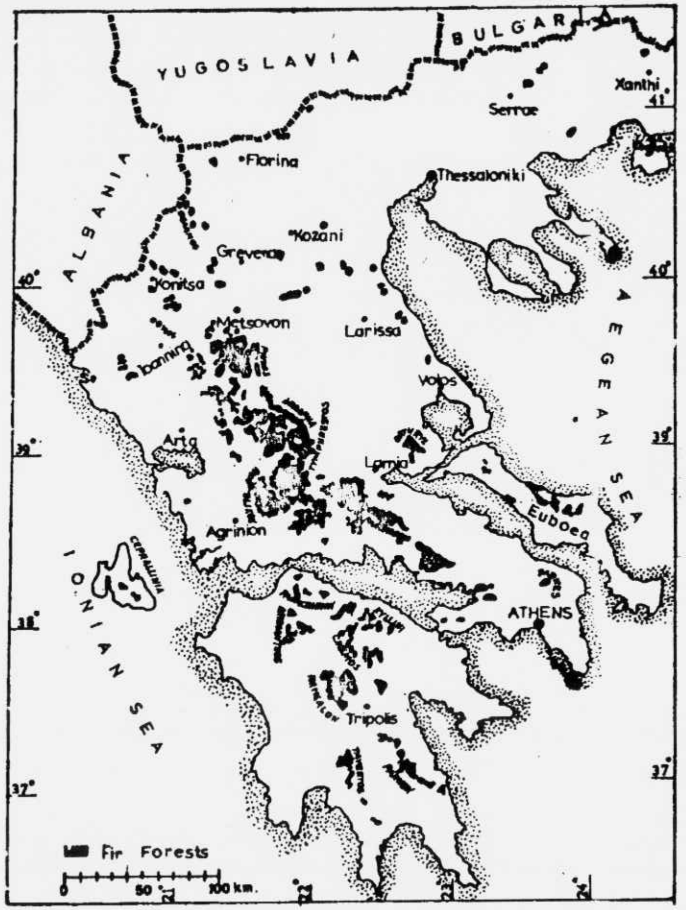


Figure 1. Distribution of fir forests in Greece

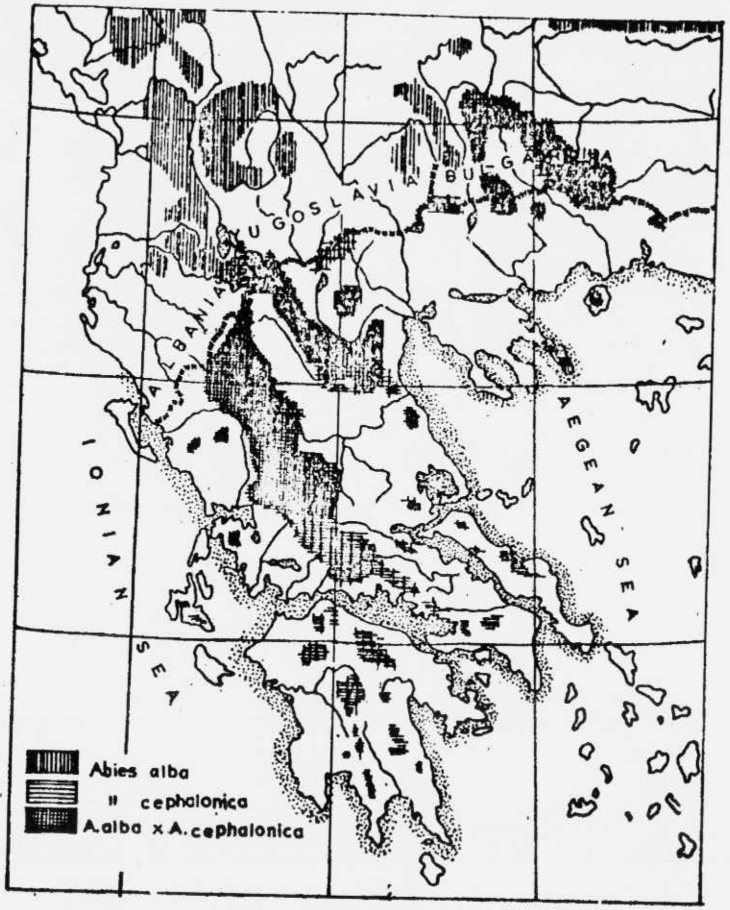


Figure 2. Distribution of fir species and hybrids

Within its natural range precipitation ranges from 600 mm to 1400 mm but with a relatively dry period from May to September. Where site conditions appear to be about optimum, the annual precipitation is between 1000 and 1400 mm. Temperature extremes range from —20° C to 33° C. (Mariolopoulos 1938, Kossenakis 1947, Makris 1962).

Greek fir is a slow starter species, seedlings require 4 to 5 years to reach a height of 20 cm. and in the first 10 years do not grow more than 50 to 60 cm. Growth accelerates markedly from 20 to 40 years and lasts for a long time. Individual trees on good sites attain a maximum height of about 30 meters and occasionally have diameters over 1.00 meter.

It is a shade tolerant species and may live under shade for 60 years or more, and then has the ability to recover and grow normally (Daphis 1968, Panagiotidis 1965).

Specific gravity, based upon whole tree data obtained from disks and estimated on volume when dry and weight when over-dry, was found to be 0,426 (0,389 to 0,437). Tracheid length based upon breast height samples, was found to be 3,533 mm for early wood and 3,923 for late wood. (Papamichael 1962 and unpublished). Insect enemies of *A. cephalonica* are many (Kailidis and Georgevits 1972) and among them the bark beetles *Gryphalus piceae* Ratz and *Pityoctenes (Ips) spinidens* Reitt, as well as the flatheaded borer *Phaenops Knoteki* Reitt, are the most destructive ones.

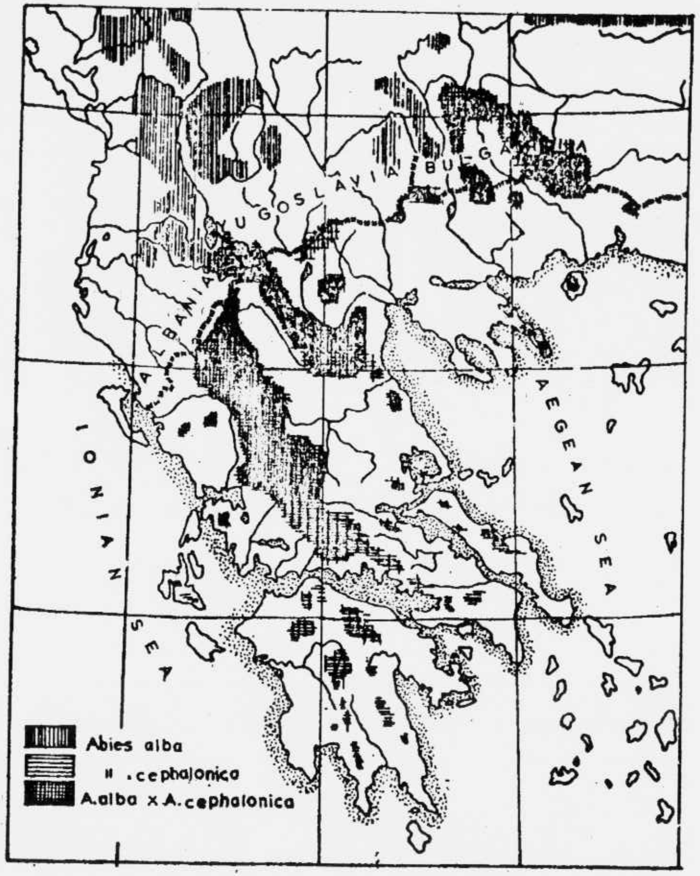
2. SEXUAL AND ASEXUAL REPRODUCTION

Greek fir is a monoecious species. Isolated trees may reach sexual maturity at the age of 20 to 25. In stands, under natural conditions, seed production does not begin until about the age of 30 to 35. Seed production lasts many years and reaches its maximum at the age of 60 to 100.

Female flowers are confined normally to the upper part of the live crown, at right angles to the axis of the last year's branchlets. They are sometimes situated at a considerable distance from the tip of the main branch, so in the case of artificial pollination, it is necessary the use of large selfsupporting bags to isolate the flowers.

Male flowers are borne in groups on the undersides of the branchlets of the last year's growth, over much of the crown, normally on the lower branches. They become noticeable in the fall and by mid-winter their presence is quite pronounced. When they reach maturity their color is of carmine-red, but there is also a proportion of trees bearing green, yellow or purple color male flowers.

Anthesis occurs in general, at the beginning of May, but there is a pronounced variation of more than ten days in time of pollen shed-



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Anthesis occurs in general, at the beginning of May, but there is a pronounced variation of more than ten days in time of pollen shedding among localities,altitudes and individuals. Pollen dispersal distance has not been reported.

Mergen and Lester (1961) present a detailed description of the phenology of male flowers and pollen development, as well as of the cytology of microsporogenesis of *A.* × *borissi regis*, which very well can be extended to *A. cephalonica.*

Heavy cone crops are borne at intervals of 2 to 4 years (average 3 years), but good cone crop may also occur in the year next to a heavy cone crop. In this case, there follows a year with almost lack of cone production. (Kossenakis 1947, Moulopoulos 1951, Bassiotis 1956, Kailidis 1968).

Cones complete their external growth in early August, ripe in September and disperse their seed in October. Cones collected in August gave a small proportion of sound seeds. As the seeds are moderately large, they are seldom carried far from the parent tree. The dispersal distance of the great majority of seed is one to two times the height of parent trees.

The number of seeds per kilo varies from 10.000 to 20.000. Most variation was found among trees of the same population than among populations. In general, the average number of seed per kilo is 13.500 for the species. In a series of cone collections made at the fir forest of Cephalonia, seed yields ranged from 55 to 340 per cone, average 214. Filled seeds varied from 25 to 207 per cone, or 35% to 85% per cone, respectively.

Germination capacity based on representative samples consisting of mixed seeds, filled and empty ones, varied from 25% to 70%. Prechilling for 2 months at 3—5° C increases the rate and germination capacity. Seeds kept in refrigerator for two years at temperatures 3 to 5° C and moisture content in the range 10% to 12% preserved their germination capacity almost unchanged.

Parthenocarpy is reported to occur in the species by Mergen *et al.* (1964), but seeds produced, while they were comparable in quantity and weight with pollinated cones, failed to germinate. Selfing, however, does not reduce germination capacity in this species. This may explain the high germination capacity as well as the high frequency of albino seedlings observed in germination tests, ranging from 0 to 13% among half sib families.

Under natural conditions germination usually occurs in spring, when temperatures are favourable, but occasionally some fall germination occurs in the field (Bassiotis 1965). Germination and seedling establishment are best on mineral soils under the protective shade of parent stand. Moderate to heavy shade is not adverse to early survival but though the species can reproduce under heavy shade, growth of seedlings is extremely slow. In nurseries the application of partial shade to the seed bed is indispensable during the first two years after seeding.

Cone insects are especially damaging to greek fir and are responsible for the loss of large quantities of seeds. During some years of moderate cone crops the whole seed production may be destroyed.

According to Kailidis and Georgevits (1970) in 1966 and 1968, years of good cone crops for the fir forest of Mount Parnis, virtually the entire seed production was destroyed by insect damage.

Ernobius albietis F. and *Dioryctria abietella* Schiff., are considered to be the most destructive cone-damaging insects. *Ernobius abietis'* oviposition on cone scales occurs during May—June on Mount Parnis and the young larvae attack the cone scales at first and then move to the axis of the cone, feeding also on the tip of the seeds. The grown up larvae are mining the axis of the cone preventing normal growth and finally destroy it. The dead cones, usually curved, remain on the branches or break apart. Some cones, apparently sealed with resin may remain on the trees for some years. *Dioryctria abietella* besides cones, can also attack buds and shoots. Oviposition occurs on cone scales and bracts along the entire length of the cone. The young caterpillars feed on cone scales and seed but they do not damage the axis of the cone.

Besides cone-attacking insects, a number of seed-feeding ones can also cause considerable damage. The most serious are *Lonchaea viridana* Meig. and *Evetria (Barbara) margorotana* H. J. The former feeds only on seed, while the latter may also attack cone scales. (Kailidis and Georgevits 1968, 1970).

In nature, Greek fir reproduces exclusively by seeds. Natural asexual reproduction has not been reported. Propagation by grafting has also not been reported for the species but it is a successful method of vegetative reproduction for other species of the genus. Schreiner (1970) reports establishment of clonal seed orchards in the U. S. A., of *Abies balsamea* and *A. procera.* Morandini (1968) reports successful grafting of *A. nebrodensis* in Italy. Gathy (1961) in his experiments on grafting with *Abies grandis*, obtained better results when grafted root stocks with scions of the same species as well as by doing the grafting in winter in the greenhouse (From December to February). Lateral or side grafting was more suitable than top grafting. Blankensop and Callahan (1960) report successful rooting of *A. concolor* cuttings. The best medium for rooting of *A. concolor* was Sponge Rok.

3. GENETICS AND BREEDING

3.1. *Interspecific Hybridization*

Chromosome studies have shown that the basic chromosome number of Abies species is 12 and that their morphology is similar (Sax and Sax 1933). Furthermore, they state that the chromosomes of *A. cephalonica* and *A. concolor* are almost identical with five being clearly submedian and seven approximately median. Mergen and Burley (1964) studied the chromosome morphology of six Abies species (*A. alba, A. × borisii regis, A. cephalonica, A. firma* and *A. nobilis glauca*) and all were found to be similar. Three chromosomes appear to be submedian while the remaining 9 are more median. The karyotype is very similar to that of Pinus (Saylor 1961).

3.1.1. Artificial cross

The first reported artificial fir hybridization was carried out by Vilmorin in the year 1867, who successfully pollinated *A. pinsapo* × *A. cephalonica.* From this pollination one fertile seed was obtained and a seedling was raised, which twenty years later, in 1888 produced cones (Liu 1971).

This hybrid was named *A. × vilmorinii* Mast., and has been reported as exhibiting extreme vigor in France (Klaehn and Vinieski 1962). The seeds, which resemble those of *A. cephalonica* are fertile and a number of seedlings have been raised. In its foliage the tree resembles *A. pinsapo* except that the leaves are longer and less rigid and bear stomata on their lower surface only. Resin canals are median. The cones which are produced in abundance, have longer bracts than *A. pinsapo,* included or very slightly exserted. (Dallimore and Jackson 1966, Liu 1971).

A list of successful artificial crosses in which *A. cephalonica* or its varieties is one of the two parents, is given in table 1.

3.1.2. Natural cross

Abies cephalonica has been reported as taking part in a number of natural interspecific crosses with species growing in the region.

A. × borissi regis Mattf. is the classical example already discussed, described by Mattfeld himself in 1927 and 1930. Rheder (after Liu 1971) considers *A. nebrodensis,* an extremely rare fir of northeastern Sicily, as a similar intermediate between *A. cephalonica* and *A. alba.*

A. × bornmuelleriana Mattf. is given by Flous (1936) as having developed by hybridization between *A. cephalonica* and the Caucasian fir *(A. nordmaniana)*, during the geological time; Mattfeld (1930), however, considered *A. × bornmuelleriana* as an intermediate between *A. alba* and *A. cephalonica.*

Abies equi-trojani covering a small range in western Turkey, according to Aytug (1959) based on morphology and pollen studies, is an intermediate between *A. cephalonica* and *A. × bornmuelleriana.*

The only species wich seems not having taken part in any natural cross during the geological time, is *A. cilicica,* a fir growing in the southern region of Asia Minor today. Fossil remains of this fir were found in the Pliocene in Europe (Liu 1971).

Table 1. Summary of reported successful crosses with *Abies cephalonica* as one of the two parents.

Female \ Male	*Abies cephalonica*	*A. cephal.* var. *Apollinis*	*A. koreana*	*A. recurvata*	*A. alba*	*A. homolepis*	Date reported	Author
A. cephalonica	×[1]				×[2]		1964[1] 1965[2]	Mergen et al. Bassiotis (Personal communication)
A. cephal. var. *Apollinis*	×		×	×		×	1964	Mergen et al.
A. pinsapo	×						1898	Sargent (Klaehn and Winieski)
A. nordmaniana	×						1949	Harkens (Klaehn and Winieski)
A. balsamea	×						1960	Chiasson
A. koreana		×					1964	Mergen et al.
A. mariesii		×					1964	Mergen et al.
A. sachalinensis		×					1964	Mergen et al.

3.2. *Geographic variation*

Abies cephalonica in most of its southern range of distribution today, forms isolated populations (see figure 1), but at its northern limits there exists a transitional zone extending to the north into populations of the so-called *A.* × *borisii regis*. There is, however, no data concerning variation, provenance and inheritance of the species, inspite of the great interest by botanists, silviculturists and geneticists.

All data presented here is recent and is based mostly on a study initiated by the present author some years ago.

In the autumn of 1968, a number of populations within the range of the species as well as in the transitional zone were sampled. From each sampled population parent trees were selected at random but under restrictions according to which (1) they should possess cones, (2) they should be at least 100 meters apart, an (3) they should have one or more neighbors within 30 meters. For each tree, sampling involved sterile and fertile branches bearing mature cones. Twenty five morphological and anatomical characters were studied and recorded. Seeds obtained from these samples were used to establish provenance test (mixed seeds) and progeny test (individual seed lots). Table 2 appears a list of sampled populations.

Table 2. List of locations sampled, with latitude, longitude, altitude and number of trees

Location	Latitude	East Longitude	Altitude meters	Number of trees	Region
Cephallenia	38° 12′	20° 36′	700–1400	25	Island of the Ionian sea
Parnon	37° 07′	22° 45′	1200–1600	24	Peloponnesus
Vytina	37° 35′	22° 10′	1200–1500	25	Peloponnesus
Parnetha	38° 10′	23° 41′	950–1150	24	S. Central Greece
Euboea	38° 16′	23° 50′	600–1100	26	Island of the Aegean sea
Elicon	38° 19′	22° 53′	800–1100	9	S. Central Greece
Parnassos	38° 36′	22° 40′	1000–1900	26	S. Central Greece
Oete	38° 48′	22° 12′	800–1600	27	S. Central Greece
Fourna	39° 03′	21° 52′	1000–1400	24	S. Central Greece
Aspropotamos	39° 38′	21° 20′	1000–1300	24	Central Greece

3.3. *Morphology*

Major taxonomic features of greek fir as appear in different floras and botanical descriptions, can be summarized as following. One-year-old branchlets glabrous, leaves of lower sterile branches and young trees most radially arranged, 20 to 25 cm long with a sharp

cartilaginous point apex, those of the upper ranks shorter, curved, scarcely pungent and often rather obtuse. Upper surface of the leaves shining dark green with several broken lines of stomata near the apex, lower surface with stomatiferous bands, each of six to seven lines on each side of the midrib. Resin canals marginal. Winter buds resinous with thick keeled scales. Male flowers 12 to 18 mm long of red-carmine color. Cones cylindrical, 10 to 20 cm long and 3,5 to 4,5 cm wide, covered with resin blisters, usually with a conical tip at the apex and with bract scales exserted and reflexed, ending in a triangular point. Cone-axes conical. Cone scales triangular in outline, 2,5 to 3,5 cm long nearly by wide. Seeds triangular, 12 to 14 mm long with lustrous brown wings. Weight of 1000 seeds about 50 grams. Seedlings with 5– 9 cotyledons 20 to 25 mm long. (Bassiotis 1956, Krüssmann 1960, Debazac 1964, Dallimore and Jackson 1966, Liu 1971, Mitchell 1972).

Table 3 presents the results obtained from 12 of the studied characters, expressed in population means and ranges. All 12 traits showed significant differences at the 5 or 1 percent level, among populations.

A careful consideration of this table reveals clearly the existence of great variation within and among populations with respect to the characters just presented. However, the origin of this variation and its tendency call for a more sophisticated analysis which is not the subject of the present paper.

Besides the character included in the table 3, a number of other characters studied, need special consideration and will be discussed. Presence of pubescens on branchlets was found in samples even of populations growing in Peloponnesus. There is a definite tendency of increasing proportion, in populations growing from south to north.

Leaves with emarginate tips were found only in northern populations and out of the range of typical *Abies cephalonica*.

Position of resin canals in the leaves was studied extensively, because besides the fact of creating considerable confusion, it might also be a useful diagnostic character. Greek fir is described by a number of botanists, as having needles with marginal resin canals. According to Bassiotis (1956) shaded and on lower branches needles have always marginal resin canals, while those exposed to sunlight and on upper rank have median ones.

Abies alba is also considered as a species with marginal resin canals, while *A.* × *borisii regis* appears in several descriptions as having leaves of fertile branches with median resin canals or like *A. alba* (Klaehn and Winieski 1962, Harrison 1966, Liu 1971).

The study of a large number of trees of different age and locations gave the following results, which should be considered as conclusive. Seedlings up to five years old, at the nursery stage, all have needles

Table 3. Population means and ranges of 12 characters studied per tree

Populations	Needle length of sterile branches in cm.	Stomata lines: Upper Surface	Stomata lines: Lower surface Band A	Stomata lines: Lower surface Band B	Cones: Length cm.	Cones: Width cm.	Cone scales: Length cm.	Cone scales: Width cm.	Cone scales: Exposed width mm.	Bracts: Total length cm.	Bracts: Exserted length mm.	Seed length in cm.
Cephallenia	2,11 1,52–2,45	5,05 2,3–6,8	8,81 7,2–9,9	8,83 7,3–9,9	15,77 11,50–19,40	3,60 3,10–4,09	2,71 2,13–3,07	3,24 2,64–3,62	5,55 4,6–6,3	3,08 2,58–3,56	7,00 2,7–9,9	1,14 0,97–1,27
Parnon	2,27 1,71–2,98	4,44 0,0–9,9	8,08 6,5–9,9	8,36 7,0–9,9	17.61 14,71–22,93	3,88 3,39–4,33	3,11 2,63–4,10	3,58 2,88–4,55	6,16 4,9–8,4	3,48 3,11–4,24	6,74 1,2–9,3	1,28 1,11–1,43
Vytina	2,47 1,89–3,06	5,15 2,2–8,8	8,78 7,1–9,9	8,87 7,9–9,9	15,90 13,34–20,20	3,86 3,27–4,60	3,14 2,74–3,58	3,56 2,77–4,19	5,91 5,1–7,0	3,38 2,90–3,82	6,12 5,1–7,5	1,22 1,09–1,40
Parnetha	2,49 1,87–2,73	4,93 2,0–9,8	7,85 7,1–9,8	8,05 7,3–9,9	17,55 14,81–20,79	3,91 3,58–4,41	3,14 2,73–3,77	3,54 3,08–4,16	6,11 5,1–6,7	3,55 3,07–3,87	7,20 4,0–8,8	1,26 1,00–1,50
Euboea	2,54 1,83–3,45	5,88 4,2–8,2	8,16 6,8–9,1	8,18 6,4–9,8	18,74 15,41–22,89	3,88 3,17–4,41	2,98 2,47–3,28	3,69 3,24–4,21	6,20 5,4–7,3	3,34 2,76–4,32	7,18 *0,0–8,5	1,22 1,08–1,35
Elikon	2,20 1,82–2,64	5,34 2,5–7,4	8,95 8,0–9,9	8,76 7,8–9,8	18,48 15,60–20,80	4,13 3,60–4,40	3,29 2,92–3,93	3,79 3,26–4,09	6,34 5,8–7,7	3,45 3,06–4,25	6,22 4,0–7,7	1,27 1,14–1,38
Parnassos	2,23 1,87–3,08	4,48 1,9–9,9	8,45 6,7–9,8	8,33 6,3–9,9	16,76 11,45–20,45	3,83 3,32–4,35	3,17 2,56–3,46	3,69 3,06–4,24	6,11 5,2–7,4	3,48 2,76–4,07	6,79 3,5–9,3	1,22 1,06–1,50
Oete	2,36 1,83–3,30	4,58 1,2–7,5	8,56 6,2–9,6	8,47 6,1–9,7	17,25 12,95–22,13	3,83 3,32–4,45	3,18 2,69–4,29	3,62 2,88–4,21	6,27 5,1–6,8	3,30 2,77–4,09	5,93 3,4–7,7	1,23 1,07–1,46
Fourna	2,60 1,94–3,34	4,26 1,2–9,2	7,91 6,9–9,5	8,09 5,9–9,9	17,76 14,56–21,21	3,95 3,49–4,47	3,17 2,69–3,70	3,75 3,27–4,45	6,50 5,8–7,8	3,51 2,96–4,12	7,02 5,0–10,6	1,29 1,12–1.49
Aspropotamos	2,44 1,76–3,11	3,37 0,0–7,0	7,32 5,7–9,6	7,48 6,5–9,7	16,41 13,00–20,62	3,87 3,33–4,52	3,28 2,89–3,68	3,61 3,13–4,62	6,42 5,6–7,7	3,63 3,25–4,08	6,92 5,0–9,6	1,25 1,09–1,48

* Bract – scales hidden.

with marginal resin canals/ regardless of population and species. Cone-producing trees of Greek fir are distinguished into two types, with respect to the position of resin canals in the needles. a. Those with resin canals marginal all along the tree and b. those with resin canals marginal in the needles of the lower sterile branches, then follows a transitional zone (not specified in height) where all stages can be found on the same branch, even needles with one canal marginal and the other median, and finally the position of the canals is median for the rest of the tree. The proportion of the two types of trees varies among populations of the species, as it appears in table 4.

Table 4. Proportion of trees with needles on fertile branches having marginal or median resin canals in sampled populations.

Population	Position of resin canals Trees % Marginal	Position of resin canals Trees % Median	Remarks
Cephalonia	92	8	
Parnon	87	13	
Vytina	81	19	
Parnetha	63	37	
Euboea	33	67	
Elicon	77	23	
Parnassos	56	44	
Oete	55	45	
Fourna	18	82	
Aspropotamos	18	82	

From the table 4, it becomes clear that the proportion of trees with median resin canals increases from south to north. This pattern of variation is difficult to be explained in terms of the theory that *A. borisii regis* is a hybrid between *A. alba* and *A. cephalonica*, two species with marginal resin canals. A discussion about the evolutionary significance of the position of resin canals is presented by Klaehn and Winieski (1962).

Another character not fully studied as the previous one but with the same general pattern of variation is the proportion of trees bearing male flowers of green or yellow color.

Bract scales, as it can be seen from table 3, is a character with considerable variation, especially with respect to their length exserted from the cone scales. Most interesting is the existence of a number of trees within populations with hidden bract-scales or having exserted only the tip of the bract apex. In view of the fact that bract length, shape and position are taxonomic features for the genus *Abies*, the variation existing in Greek fir population can not be explained. The only species of the region with hidden bract scales is *A. cilicica* which grows in the southern Asia Minor.

3.4. *Provenance test*

Seeds from sampled population and some collected from the Forest Service, were sown in a nursery on Mount Parnetha, in two tests in March 1969. In test 1, mixed seeds from each population were used in a complete randomized block design with ten replications. In test 2, seeds of individual parent trees from four populations were sown separately in a modification of a randomized block design with four replications. The modification consisted of keeping the individual tree-progeny from any one population in adjacent rows in any one replicate.

At the end of the fifth growth period and before transplanting the seedlings, height measurements of both tests were performed. Table 5 presents the results obtained from nursery test 1.

Table 5. Duncan's new multiple-range test for height in cm, of 5-year-old seedlings from 10 populations. Any two means not connected by the same line are statistically different at the 0.05 level.

Rank	Origin	Mean cm
1	Vytina	22,69
2	Cephalonia	20,53
3	Parnon	19,98
4	Parnetha	19,27
5	Panaetolicon	19,16
6	Fourna	19,04
7	Parnassos	18,74
8	Elicon	18,65
9	Euboea	18,14
10	Taygetos	17,90

The results show clearly the existence of variation with respect to height growth among populations. The pattern of variation does not show any specific gradient and seems to be random, though the most eastern population and the most southern one exhibit the lowest height growth.

3.5. *Progeny test*

Analysis of variance of 40 families for total height based on individual trees of the data obtained from nursery test 2, showed significant differences among families at 0.05 and 0.01 level. Narrow sense heritability was estimated and was found $h^2 = 0.83$. The heritability estimated is quite high but this concerns seedlings growing

in nursery beds and in one environment. It has been derived from very young material, concerning the species working with and may be expected to change with time.

4. IMPROVEMENT PROGRAMS

Greek fir used to grow in much more extensive areas not long ago. Its forests have been severely damaged by continuous heavy exploitation, fires and grazing.

The fir forest of Cephalonia was estimated to cover an area of 7,200 hectares in the 16th century, while at the beginning of this century it was confined to about 1,500 hectares. (Samios 1908). Even then, some good stands with trees reaching height more than 30 meters, with good stem and crown form, could be found.

In central Peloponnesus and on the mainland there are still, however, some relatively unaltered stands, in areas where intensive exploitation was difficult or impossible until the recent development of good network of forest roads.

On this basis, it could be said that there is no shortage of genetically desirable material adapted to a variety of climatic and soil conditions. Variation in growth rate, form of stem and crown and size of lateral branches is very pronounced.

Plantations of Greek fir are not extensive today and are confined to cover openings of the main forest under management. Improved seed will become important in the future, in view of the extensive areas covered today by remnants of fir forest which should be converted to productive forest, and the increasing demand of seed of that species from other Mediterranean countries.

The development of an improvement programme should be based upon data on the inheritance of character we are interested in, the magnitude and the nature of the existing variation.

Data, available today, on variation in growth rate comes from observations and measurements of natural stands. This is not a sare gulde, since it is not known if this is primarily attributable to genetic or to nutritional differences of the site. Common environment experiments are restricted and concern only results obtained from five-year-old seedlings at the nursery stage. These results indicate that provenance selection might give worthwhile gain and that variation in progeny means from individual trees is substantial and even greater in magnitude to variation among provenances.

Results from morphological and anatomical studies already reported, indicate that there are significant differences in a number of characters among populations, while in others there is a clinal type of variation from south to north, or from east to west. The within populations variation in these characters is also considerable. In general, however, the variability pattern is not clear enough and more research is needed in that direction.

This preliminary information shows that the best approach to improvement of Greek fir is individual tree selection and establishment of clonal seed orchards.

Until more information is available concerning clinal or ecotypic variation through studies, such as seed source tests, the number and locations of seed orchards to be established will be determined by geographic and physiographic boundaries. The first obvious break down for the Greek fir is the Peloponnesus populations from the ones growing on the islands and the mainland.

Within this primary division further subdivisions may be justified based on soil, climate, site index and the structure of particular populations within each major geographic division. At this initial stage each seed orchard must comprise a large number of clones so that a broad genetic basis can be maintained.

Artificial hybridization is also an important tool in forest tree breeding. Work on hybridization indicates that species within the Mediterranean region are especially prone to hybridize, some of which exhibit extreme vigor as f. e. *A. pinsapo* × *A. cephalonica* in France. Interspecific hybridization of *A. cephalonica* with species of the Mediterranean region and especially with ones growing in Asia Minor on similar ecological conditions, might prove to be a promising method of improvement.

At present as an interim source of seed to meet the needs of the Forest Service, best stands of fir forest have been converted into seed production areas. Vigorous, well-formed and disease-free threes within each stand have been selected and marked, providing the necessary quantity of seed. Seed zones have also been determined, based on geographic and physiogeographic boundaries. This approach to the problem of meeting the current seed needs for afforestation purposes, is not restricted only to *Abies cephalonica* but it is also followed for all fir forests of Greece. For this particular species, two seed zones have been determined, one of Peloponnesus and Cephalonia island and the second of the rest of its distribution.

Within each zone, seed production areas provide the necessary quantity of seed for each particular zone as well as the seed which is exported to other Mediterranean countries. It should be mentioned that the seed production areas established for the Greek fir do not correspond to the known standard type applied for such operations, as the selection of a plus stand, elimination of undesirable phenotypes and establishment of isolation barriers to foreign pollen. Instead, desirable phenotypes over a number of plus stands have been selected and properly marked while inferior phenotypes are being eliminated by the usual forestry practice. This was imposed after the amount of variation revealed by our preliminary morphological, anatomical and common environment studies. In this way, it is

secured not only a seed source of known geographic origin but also a broad genetic basis of the seed collected. The establishment of such a broad genetic basis is considered as of primary importance for the Greek fir, not only because of the variation which exists within populations but also of the great variation of the sites (soil and climate), where the planting stock is used.

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Forest Research Institute
Terma Alkmanos, Athens 615, Greece

MONOGRAFIJA *APIES CEPHALONICA* LOUDON

Grčku jelu *Abies cephalonica* prvi je put utvrdio i opisao 1838. godine Loudon, kao posebnu vrstu roda *Abies*.

Njezino područje rasprostranjenja odredio je Mattfeld koji je osim toga ustanovio da sjeverno od planine Oxya (38° 50′ sj. š.) ne dolazi više tipična i čista grčka jela već samo populacije hibridnog karaktera. Prema Mattfeldu hibride treba smatrati rezultatom spontanog križanja između *Abies cephalonica* i *Abies alba* iz centralne i južne Evrope. Sada je ustanovljeno da se hibridi rasprostiru prema jugu do Peloponeza.

U području rasprostranjenja tipične grčke jele (sl. 1) nije ustanovljena niti jedna druga vrsta ili varijetet.

Grčka jela raste na različitim tlima na nadmorskoj visini od 400 do 2000 m, a ponekad i više. Ona tvori često čiste sastojine, ali također vrlo često i mješovite sastojine s crnim borom (*Pinus nigra* Arn.).

Sastojine grčke jele počinju rađati sjemenom poslije tridesete godine. Ova vrsta rađa sjemenom dugi niz godina i dostiže maksimum kod starosti sastojina od 60 do 100 godina. Puni je urod u prosjeku svake treće godine.

Cvatnja je u mjesecu svibnju a sazrijevanje sjemena u rujnu, dok je rasijavanje sjemena u mjesecu listopadu. 1 kg sjemena sadrži u prosjeku 13.500 sjemenki.

Umjetno su proizvedeni hibridi s brojnim vrstama jela koje dolaze u području Sredozemlja, kao i drugih područja u svijetu. Mnogi smatraju da su dobiveni brojni prirodni hibridi ne samo s običnom jelom *(Abies aiba)* nego također s drugim vrstama jela koje rastu u mediteranskom području.

Na osnovi istraživanja velikog broja morfoloških i anatomskih svojstava grčke jele ustanovilo se da postoje znatna variranja između različitih populacija, kao i unutar iste populacije.

Ustanovljena je očita tendencija povećavanja postotka učestalosti nekih svojstava idući od juga na sjever. Varijabilnost oblika brakteja i duljina njihovih produljenih vrhova ne može se objasniti već prije opisanim mišljenjima o prirodi i evoluciji grčke jele.

Pokusi postavljeni pod istim vanjskim uvjetima pokazuju diferencijaciju vrste s obzirom na brzinu rasta u visinu te visoki stupanj nasljednosti tog svojstva.

Na temelju dosadašnjih dostignuća smatra se da program oplemenjivanja treba da se osniva na izboru najboljih fenotipova i podizanju klonskih sjemenskih plantaža u svakom većem geografskom i fiziogeografskom području rasprostranjenja ove vrste. Pokusi provenijencija i izučavanja potomstva točno će odrediti broj potrebnih sjemenskih plantaža, kao i područje u kojem će se koristiti genetski poboljšano sjeme koje je proizvedeno u sjemenskim plantažama.

Napokon, može se potvrditi da stvaranje umjetnih hibrida između grčke jele i drugih vrsta jela iz Male Azije, koje rastu pod sličnim ekološkim uvjetima, može biti dobra metoda oplemenjivanja.

CONSTANTINOS P. PANETSOS

MONOGRAPHIE D'*ABIES CEPHALONICA* LOUDON

Le Sapin grec *Abies cephalonica* a été décrit et reconnu pour la première fois en 1838 par Loudon comme espèce particulière du genre *Abies*.

Son aire d'extension a été déterminée par Mattfeld, qui a constaté, de plus, qu'au nord de la montagne Oxya (latitude 38° 50′ de Nord) poussent des populations de provenance hybridogène et non pas des populations de sapin grec typique et pur. Les hybrides étaient considérés par Mattfeld comme le résultat de croisement naturel entre l'*Abies cephalonica* et le sapin de l'Europe centrale et de l'Europe du Sud, *A. alba*. Aujourd'hui on a découvert que les hybrides s'étendent vers le sud jusqu'à Péloponnèse.

Dans l'aire d'extension du sapin grec typique (voir plan 1) on ne reconnaît aucune autre espèce ou variété.

Le sapin grec pousse sur une diversité de sols et à une altitude de 400 mètres à 2.000 mètres et plus. Il forme souvent des peuplements purs, mais aussi, bien souvent, des peuplements mélangés avec le pin noir (*Pinus nigra* Arn.).

La fructification des peuplements commence après la trentième année, elle dure pendant longtemps et atteint le maximum à l'âge de 60 à 100 ans. La fructification abondante se répète toutes les trois années en moyen.

La floraison a lieu pendant le mois de mai, la maturité des graines au mois de septembre et la dissémination en octobre. Un kilo de graines en contient 13.500 graines en moyen.

Il produit des hybrides artificiels avec un nombre considérable tant d'espèces du genre de la région Circumméditerranéenne que d'espèces de Sapin poussant à d'autres régions du monde. Plusieurs considèrent aussi qu'il a produit beaucoup d'hybrides naturels non seulement avec l'*A. alba*, mais aussi avec d'autres espèces de sapin poussant dans la région Mediterranéenne.

Une recherche morphologique et anatomique d'un grand nombre de caractères de sujets de sapin a prouvé l'existance d'une variété considérable en parmi les différentes populations et même dans la même population

On a constaté une tendance claire d'augmentation du pourcentage de la présence de quelques caractères allant du sud vers le nord. On a constaté aussi une présence de caractères, comme la forme de bractées et la longueur de leur partie échappant des écailles, dont la variation ne peut pas être expliquée par les points de vue déjà formulés sur la nature et l'évolution du sapin grec.

Des expérimentations dans le même milieu ont démontré la différentiation de l'espèce en ce qui concerne la vitesse de l'accroissement en hauteur et la grande hérétabilité de ce caractère.

A la base des données, bien que limitées, on pense qu'un programme d'amélioration doit se bafonder sur la sélection des meilleurs phénotypes et l'installation de vergers à graines de clones dans chaque grande division géographique et physiogéographique de son aire. En plus, des essais de provenances et de descendants détermineront exactement le nombre des vergers à graines nécessaires et l'aire dans laquelle on utilisera les graines génétiquement améliorées, produites de ces vergers.

Enfin, il est possible de prouver que la création des hybrides artificiels entre le sapin grec et des espèces de sapin d'Asie Mineure, ayant des exigences écologiques semblables, est aussi une bonne méthode d'amélioration.

Figure 3. Greek fir forest at Vytina, Peloponnesus

Figure 4. Needle of sterile branch (long) and fertile branch (short)