Climate Change and Its Impacts upon Occurrence of Natural Hybrid Firs

***Cemil ATA, Bengi KORGAVUS**
Yeditepe University, Fine Arts Faculty, Landscape Architecture Department, Istanbul
*Corresponding Author: acemil@yeditepe.edu.tr

Summary

Abies equi-trojani Ashers et Sinten and *Abies olcayana* Ata and Merev are two fir hybrids distributed in the west of Turkey. These two firs are natural hybrids occurred in nature under severe climate changes. There was no human effect upon occurrence of these hybrid firs.

Mattfeld (1925) claimed that long ago there were forests of firs surrounding the Mediterranean Sea through Asia Minor, Europe and some parts of North Africa. Later, the climate changed and the areas of fir became isolated from each other, surviving in the mountains and developing individual traits now recognized in Abies equi-trojani.

Three major cities are to be found in the north west of Turkey: Bursa, Canakkale and Balikesir. Uludag (Mt. Olympus, 2543 m) is near Bursa and *Abies bornmulleriana* Mattf. occurs on it, Kazdagi (Ida Mountain, 1767 m) is between Balikesir and Canakkale and *Abies equi-trojani* is distributed on it, and Cataldag (1336 m) is between Balikesir and Bursa, and Cataldag fir (*Abies olcayana*) is found on it. The distances between these mountains are 100 - 200 km, the different fir species occur at high elevations in these mountains.

Key Words: Climate Change, Natural Hybrids, Pure Stands, Mixed Stands, Firs

Introduction

The most general definition of climate change is a change in the statistical of the climate system when considered over long periods of time, regardless of cause. On the broadest scale, the rate at which energy is received from the sun and the rate at which it is lost to space determine the equilibrium temperature and climate of Earth. This energy is distributed around the globe by winds, ocean currents and other mechanisms to effect the climates of different regions.

Nowadays it is obviously accepted by nearly all scientists and scientific institutes that climate change has already triggered plant species distribution in many parts of the world. Increasing impacts are expected for the future, many studies have aimed for a general understanding of the regional basis for species vulnerability. According to the research results of '*climate change threats to plant diversity in Europe'* the boreal region was projected to lose few species, although gaining many others from immigration and the greatest changes are expected in the transition between the Mediterranean and Euro-Siberian region. Scientists of this research found that risks of extinction for European plants may be large, even in moderate scenario of climate change (Wilfried, 2005). When aggregated over time, subtile changes in these rates may also have profound effects on ecosystem composition, structure and function (Parmesan et al., 2000).

Another important research study (Harman, 2006) has been carried out by Andreas Harmann titled *'Potential effects of climate change on ecosystem and tree species distribution in British Colombia'*. According to the result of this research tree species with their northern range limit in British Colombia gain potential habitat at a pace of least 100 km per decade, common hardwoods appear to be generally unaffected by climate change, and some of the most important conifer species in British Colombia are expected to lose a large portion of their suitable habitat. The extent of spatial redistribution of realized climate space for ecosystems is considerable, with currently important sub-boreal and mountain climate regions rapidly disappearing. Local predictions of change to the tree species frequencies were generated as a basis for systematic surveys of biological response to climate change.

Over the last decades, western North America has experienced record temperatures and periods of drought that have been attributed to global climate change (Hoerling and Kumar, 2003). Droughts from 2001 to 2003 caused major forest tree mortality in Western Canada (Hogg et al., 2008) and across Southwestern North America woodlands. Indirectly, climate change has been recognized as a contributing factor to outbreaks of forest pests and diseases that have caused episodic tree mortality throughout Western North America (Woods et al., 2005).

Natural climate cycles and climate variability may play a role in these observations, but they nevertheless raise the question how species will respond to further climate change. Continued temperature increases are expected especially for northern latitudes and increased drought is expected for the southern latitudes in America and Europe, especially in Mediterranean region. Using the fossil woods and fossil needles of fir species as research materials, Huiling Sun and his research group have studied the fir trees disappeared 500 years ago in the Liupan Mountains in China and concluded that fir trees of coniferous species had continuously existed around Tianchi Lake in Liupan Mountains until 530 cal yr BP (calibrated year before present) and fir trees retreat before 2200 cal yr BP was probably triggered by regional climatic forcing while the more rapid decline after 2200 cal yr BP and the extinction around 530 cal yr BP (Huiling et al., 2011).

Palaeo-ecological work has shown that the eventual response of a species to a change in climate is an adjustment in range, as the organism re-aligns its distribution in accordance with its climatic tolerances. Range adjustment may take the form of actual migrations of more mobile organisms, the establishment of new populations of species where climatic regimes become more favorable, and the extirpation of other populations in regions where climatic conditions became less favorable (Dockerty et al., 2003).

Recent global warming is strongly affecting territorial ecosystems by shifting the ranges of plant and animal species poleward and upward. An increasing number of studies on the upward shift of the range of plants in alpine ecotones have been conducted in Europe and North America (Beckage et al., 2008). Climate change is expected to decrease or even eliminate the habitats of alpine and subalpine plants because these plants are isolated on high mountains. Thus, these plants are particularly sensitive to global warming (Horikawa et al., 2009).

Global climate change has already had observable effects on the environment. Glaciers have shrunk, ice on rivers and lakes is breaking up earlier, plant and animal ranges have shifted and trees are flowering sooner. We have high confidence that global temperatures will continue to rise for decades to come, largely due to greenhouse gasses produced by human activities. The Kyoto protocol has focused the attention of the public and policymakers on the earth’s carbon (C) budget. Year by year carbon budget is getting bigger and bigger around the world and the temperature is getting higher and higher, drought is getting a dangerous level on the natural distribution of the plants including fir species. Because the fir species are very sensitive to drought and high temperature.

Mattfeld (1928) claimed that long ago there were forests of fir surrounding the Mediterranean Sea through Asia Minor, Europe and some parts of North Africa. Later, the climate changed and the areas of fir became isolated from each other, surviving in the mountains and developing individual traits now recognized in *Abies bornmulleriana*, *Abies equi-trojani* and *Abies olcayana*.

Coode and Cullen classify the fir species in Turkey into two species as *Abies nordmanniana* and *Abies cilicica* and mention the other species *Abies bornmulleriana* and *Abies equi-trojani* as subspecies of *Abies nordmanniana* (Yaltırık 1973). On the other hand, Lui (1971) stated that *Abies bornmulleriana* was a natural hybrid between *Abies cephalonica* Loud and *Abies nordmanniana* and he also claimed that *Abies equi-trojani* was a synonym for *Abies cepholonica var graeca* (Fraas). Aytug (1959) mentioned that *Abies equi-trojani* was a natural hybrid between *Abies cephalonica* and A*bies bornmulleriana.* These sophisticated descriptions of fir species in Turkey will be discussed in this research.

In this paper the features of *Abies olcayana* which is believed that it is a natural hybrid occurred naturally in the west of Turkey during the times of climate changes surrounding the Mediterranean Sea will be explained.

Description of species

Botanical nomenclature

Family name: Pinaceae
Genus: Abies
Latin name: *Abies x olcayana* Ata and Merev
Local name: Chataldag Goknari (Chataldag fir)

Botanical description

Evergreen tree, 25-30 m tall, bole straight, cylindrical, up to 60-70 cm diameter, free of branches for 12-15 m. Lateral branches in whorls of four to six, more or less horizontal, ascending on the upper bole. Crown pyramidal in both young and old trees. Bark on the upper bole and branches grey and thin, on the lower bole dark grey and slightly thicker.

Young shoots glabrous, glaucous-green, becoming reddish brown or brown. Buds oblong-conical surrounded by leaves at the base, slightly resinous or mostly not resinous, 5-8 mm long, usually reddish brown. Leaves linear-oblanceolate, those on the upper branches short (1-2 cm), on the lower branches long (2-3 cm), 2-2.5 mm broad, obviously emarginated (notched) on the lower branches whereas acute or obtuse on the upper branches, two whitish line of stomata on the lower surface, leaves have two resin canals, mostly lustrous dark green above and pale green below. The arrangement of leaves varies according to the location of the branchlets. Leaves on the lower branchlets under low light intensity are distichous or pectinate in arrangement with the two lateral sets of leaves arranged in a horizontal plane, but on the upper branchlets under high light intensity they are pectinate, but somewhat obliquely arranged in two or three rank below, densely covering the branchlets in imbricated ranks above. Male flowers oblong-ovate, 10-15 mm in length, 4-6 mm in width, surrounded at the base by many protective scales, purplish-red or reddish-brown when the pollen matures, their points of attachment remain on branchlets, the woody cuplike bracts persist 10-15 years. The number of abnormal pollen grains is more than 50 percent of the total. Female flowers erect solitary mostly in the upper portions of the crown, covered with many scales at the base, the color is light brown. Mature cones cylindrical, tapering to a short pointed nipple like apex, green and reddish brown when young, changing to brown at maturity, 8-12 cm long, 2-4 cm diameter, bract scales exerted from the cones with a square shaped plate. Cones lose their scales in November-December but the conical cone-axis remains attached to the branchlets. Seeds wedge-shaped, with three or more resin vesicles on the surface and a resinous odour, 5-8 mm long, 4-7 mm wide. Seed-coat thin and papery.

External morphological features

The form of Abies olcayana is pyramidal, the stems are straight and wolf trees are absent. Young shoots are glabrous and bright brown. The bark is thin and grey.

The external morphological features of Abies olcayana are not significantly different from those of *Abies equi-trojani* or *Abies bornmulleriana.* The general appearance, shoots, needles and cones of these three fir species are very similar with only slightly differences between needles and buds. They are difficult to differentiate using external morphology, various researchers disagreeing on morphological features. Krause (1936) said ‘slightly resinous’ for the buds of Abies equi-trojani, whereas Kayacik (1967) stated that they were ‘not resinous’ and contrary to Kayacik, Gokmen (1970) described them as ‘resinous’. Code and Cullen (1965) mentioned they were ‘not resinous’ and the same researchers used ‘acute’ for the needles of *Abies equi-trojani*, whereas Gaussen on his trip to the Ida Mountain in 1973 stated that they were ‘from obtuse to emarginated’. As a conclusion, only external morphological features of the fir species are not enough for definite identification.

When we consider and compare the differences of external morphological features of firs distributed in Turkey we can easily seen that *Abies olcayana* differs from the *Abies cilicica* distributed on the Taurus Mountains. Bract scales of cones of *Abies cilicica* are not excreted from the cones, whereas in *Abies olcayana* they are. Similarly *Abies olcayana* also can be distinguished easily form *Abies nordmanniana* by the shape of young shoots and the buds. Young shoots of Abies nordmanniana are hairy whereas those of *Abies olcayana* are glabrous. Only slight differences exist in resin content of the buds. The most common features seen in *Abies bornmulleriana, Abies equi-trojani* and *Abies olcayana* are that the young shoots are glabrous, buds are resinous or non-resinous, bract scales of cones exsert from the cones and the leaves are variable from the obtuse to emarginate or somewhat acute.

Yaltırık (1973) suggested that visible morphological features alone are not enough to justify, separate descriptions and inner morphology such as pollen morphology and wood anatomy are essential in order to study modern taxonomy. Both of these features were studied to compare *Abies olcayana* with other species distributed in Turkey.

Pollen morphology

Pollen morphology of the species cannot be changed and remains a stable characteristic (Aytug, 1959). For this reason we investigated the pollen characteristics of Abies olcayana and compared the findings with those of *Abies nordmanniana, Abies equi-trojani* and *Abies cilicica* which were investigated by Aytug (1967).

The pollen dimensions of different species are not the same. Especially the pollen grains of Abies equi-trojani and Abies olcayana are very different. In order to obtain more detailed investigations the dimensions of pollen which were taken from *Abies olcayana* were compared with the dimensions of pollen of *Abies nordmanniana, Abies bornmulleriana, Abies equi-trojani* and *Abies cilicica* by ***'t'*** test. According to the results of **'*t*'** test, all dimensions of pollen of Abies olcayana are significantly different from the dimensions of pollen of other 4 fir species distributed in Turkey (Ata and Merev, 1987). These results show that the pollens of Abies olcayana do not belong to the other four fir communities, they belong to a different community.

Not only the differences of pollen dimensions but the differences of sculpturing on the pollen air-sacs are also very important characteristics for recognizing a species (Aytug, 1967). Arbez (1969) and Gokmen (1970) claimed that the fir distributed on Chataldag Mountain was the same species *Abies equi-trojani*, distributed on Ida Mountain. However the sculpturing on pollen air sacs and the dimensions of pollens of these two fir species show that these two fir communities are different, not the same.

As citied by Aytug, the authors Van Campo, Gussen and Moss, claimed that the amount of abnormal pollens of hybrid trees are more than 50% of total and the dimensions of these pollen grains are in a very large variation (Aytug, 1967). The dimensions of pollen grains of Abies olcayana show a large variation and the amount of abnormal pollen grains are more than 50%. Many atrophied pollen grains and pollen grains without air-sacs or with three air-sacs are commonly seen in this species.

According to these characteristics obviously it can be said that this fir is a natural hybrid developed during the time of long term in accordance with the changing climate like the other natural hybrid, *Abies equi-trojani.*

When we consider the total features of pollen grains of firs distributed in Turkey, five different fir communities can be distinguished.

Wood anatomy

Wood anatomies of four fir taxa, naturally distributed in Turkey, were investigated by Aytug in 1961. The same features of *Abies olcayana* were studied in this research and compared with the features of the other four fir species (Table 1).

Table 1. Inner morphological features of *A. nordmanniana, A. bornmulleriana, A. cilicica, A. equi-trojani and A. olcayana.* The numerals of *A. nordmanniana, A. bornmulleriana, A. cilicica, A. equi-trojani* were taken from Aytug (1961)

Species	Tracheids												Pit-pairs on the vertical tracheids come in contact with ray parenchyma cells				Rays					
				Early wood		Late wood							Early wood		Late wood					Max. height		
0	number of pits in a mm²	crassulae	number of consecutive pit-pairs	diameter of areoles (micron)	diameter of pores (micron)	diameter of areoles (micron)	diameter of pores (micron)	length (mm)	width (micron)	thickness of the wall (micron)	longitudinal parenchyma	longitudinal resin duct	Type	diameter (micron)	Type	diameter (micron)	mean number	forms	series	cell	micron	width (micron)
A. nordmanniana	680	very rare	4	19	7	12	5	2.875	43.00	5.57	—	—	Cupresso-ide	5	Cuppresso-ide and Piceoide	3.5	2	Homoge-neous biseriate	Uniseria-te rarely	29	550	50
A. bornmulleriana	600	rare	4	20	9	10	3.5	3.347	38.91	7.64	—	—	″	6	Piceoide	3.5	3	″	″	34	630	35
A. cilicica	700	very rare	2	18	5	14	4	2.654	34.09	5.88	—	—	″	5	″	4	2	″	″	28	490	22
A. equi-trojani	760	exist	6	20	6	11	4	3.335	40.54	5.31	—	—	″	5	″	3	2	″	″	53	720	25
A. olcayana (Chataldag fir)	1018	exist	13	16	5,55	10	3.7	3.082	43.97	4.99	—	—	″	5,5	″	2.77	2	″	″	49	1008	22

The characteristics of tracheids determined on early wood and late wood separately. Lengths of tracheids are similar on the early wood and late wood, and the general mean is 3.082 mm.

Widths of tracheids are significantly different from each other, and general mean is 43.97 microns.

Pit-pairs are generally uniseriate and biseriate on the radial walls of tracheids. Biseriate pit-pairs, which are very rare, can be seen as 13 pairs and generally they are in the shape a triangle or an ellipse. Uniseriate pit-pairs are round when they are close to each other. Frequently, some crassulaes between pit-pairs can be seen. 1018 pit-pairs have been counted in an mm². The diameter of big pit-pairs is 16 microns and of those pores of big pit-pairs 5.55 microns. However the diameter of small pit-pairs 10 microns and of the pores of small pit-pairs 3.7 microns on the tracheids of late wood.

Where the vertical tracheids come in contact with ray parenchyma cells, the types of pit-pairs are ‘cupressoide’ in early wood and ‘piceoide’ in late wood. The diameter of cupressoide type pit-pairs is 5.55 microns and piceoide type pit-pairs 2.77 microns.

Rays are homogeneous, uniseriate or rarely biseriate. Maximal cell height is 1008.0 microns and maximal number is 49, and maximal width is 22 microns. Some calcium oxalate crystals were seen on the rays.

There are no resin ducts in the wood of firs but in some circumstances (pressure, frost or wound) traumatic vertical resin ducts can be seen in the wood. These are pathological resin ducts. In this study some pathological resin ducts were seen in the wood. These resin ducts appear frequently in the wood in accordance with the type of wound (Fahn, 1974). Epithelial cells of those ducts in the wood of fir, contrary of those of pines, are thick and lignified. Pathological resin ducts die in the same years of establishment and produce small amounts of resin (Esau, 1965). Axial parenchyma cells were rarely seen in the wood. Sometimes these axial parenchyma cells make group through the rays.

When the anatomical features of wood of Abies olcayana are compared with the features of wood of other firs, the differences can be seen easily (Table 1).

In the wood of *Abies olcayana* the number of biseriate consecutive pit-pairs, seen on the tangential walls, is up to 13, but this number is very small in the woods of other firs. This is a very important feature for recognizing a species (Aytug, 1961). The diameter of pit-pairs in the wood of *Abies olcayana* is smaller (2.77) than those of *Abies equi-trojani*. Maximal cell height of rays is 1008 microns and the number is 49 in the wood of Abies olcayana, whereas they are 720 microns and 53 in the wood of *Abies equi-trojani*. These different anatomical features show that this fir distributed on

Chataldag, belongs to a different fir community.

Four native fir species have previously been identified in Turkey. *Abies nordmanniana* in the north-east, Abies bornmulleriana in the north-west, *Abies equi-trojani* in the west and *Abies cilicica* in the south. The fir distributed on Chataldag (*Abies olcayana*) which is between the distribution areas of *Abies equi-trojani* and *Abies bornmulleriana* has been called as *Abies equi-trojani* by Gokmen and Arbez, however, the more detailed investigations on pollen morphology and wood anatomy show that the fir distributed on Chataldag is not Abies equi-trojani, but Abies olcayana. In fact the external morphological features of these there fir taxa (*Abies bornmulleriana*, *Abies equi-trojani* and *Abies olcayana*) are almost similar but pollen morphology and wood anatomy are significantly different.

The dimensions of pollen grains of five fir taxa are significantly different. The pollens of *Abies olcayana* do not belong to the other four fir communities. They belong to a different and previously unidentified community. Likewise the sculpturing on the air-sacs of *Abies equi-trojani* is significantly different from that of Abies olcayana. These differences of dimensions and sculpturing of pollen grains and air-sucs of the two fir taxa show that these two fir communities are different.

The dimensions of pollen grains of Abies olcayana are in a large variation and over 50% of grains are abnormal. Many atrophied pollen grains and grains without air-sacs or with three air-sacs are commonly seen in Abies olcayana. These characteristics suggest that this fir is a natural hybrid developed during geological time under severe climate change, like the other natural hybrid, Abies equi-trojani. Wood anatomy of *Abies nordmanniana*, *Abies bornmulleriana*, *Abies equi-trojani* and *Abies cilicica* had been investigated by Aytug and the same features of Abies olcayana were studied in this research and compared with the features of other fir species. In the wood of Abies olcayana the number of biseriate consecutive pit-pairs, seen on the tangential wall, is up to 13, but this number 6 or less in the woods of other firs. This is considered significant when recognizing a species. The diameter of pit-pairs in the wood of *Abies olcayana* is much smaller when compared with that of *Abies equi-trojani*.

When the anatomical features of wood of *Abies olcayana* are compared with the features of other firs the differences can be easily seen. These different anatomical features show that this fir, distributed on Chataldag, belongs to a different fir community, and considering the number of its abnormal pollen grains, this new fir taxon should be accepted as a natural hybrid, and called *Abies x olcayana* Ata and Merev, as a fifth fir taxon distributed in Turkey.

The other important point is that this new fir taxon grows faster, than *Abies nordmanniana*, *Abies bornmulleriana* and *Abies cilicica*, maybe it is because of hybrid vigor.

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