

Ecological attributes and distribution of Anatolian black pine [*Pinus nigra* Arnold. subsp. *pallasiana* Lamb. Holmboe] in Turkey

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Abstract

The aim of this study is to determine ecoregions and the effect of ecological properties on natural distribution of Anatolian black pine [*Pinus nigra* Arnold. subsp. *pallasiana* Lamb. (Holmboe)] in Turkey. The results suggest that 6 ecoregions exist and climate, parent material, topography, anthropogenic factors, floristic composition, competition are ecological factors that determine the distribution of Black pine in Turkey. But, climatic elements such as precipitation and temperature are the dominant factors. The six ecoregions with different characteristics have been identified and distribution of Anatolian black pine revealed depending on ecological features of each region. Each region has its own characteristics that affect the growth and distribution of black pine. Productive black pine forest are found on the subhumid-semiarid areas receiving humid air mass coming from the seas either on northern or southern coastal mountains of Turkey. The poor and/or lowest productive stands occur in the semiarid parts of Inner Anatolia. Black pine can grow on all material in the semi-arid and sub-humid cold climates, but deep weathered parent materials are the best for growing of black pine.

Key words

Ecology, Forest, *Pinus nigra*, Turkey

Introduction

Black pine is native to Europe and Asia and extends from Spain and Morocco to eastern Turkey, south to Cyprus, and north to northeastern Austria and Crimea, Ukraine. In United States, European black pine is widely planted in northern states in New England, around the Great lakes, and in the Northwest (Van Haverbeke and David, 1990). In Turkey at present 21.3 million ha of forested land cover 27% of the territory of Turkey, of which 10.9 million ha (51%) are productive forest. The remaining forest land of 10.4 million ha (49%) is forest land either with low yield or no yield at all, consisting of degraded coppice, maquis and shrubs. Conifer forests cover 56% of Turkey's productive forest area. About 45.400 ha, land area in Turkey has been afforested in 2009 in Turkey.

Turkey is situated at the intersection of three phytogeographical regions: Euro-Siberian, Mediterranean and Irano-Turanian. Their distinctive vegetation reflects differences in climate, geology, topography, soils and floristic diversity, including endemism. Scientific and historical research indicates that 4,000 years ago the Anatolian landscape was 60-70% forest and 10-15% steppe (Davis, 1965-1985; Davis *et al.*, 1988). However,

overgrazing, over-cutting, fires, clearance for agriculture, wars and general misuse of the land have caused a decrease in forest area to 26% and an increase in steppe area to 24% (Mayer and Aksoy, 1986). Ninety percent of Turkey's forests are 'natural' in origin and contains over 450 species of trees and shrubs (Çolak and Rotherham, 2006).

Ecologically, Turkey has a potential of 75-80 % of forest. However, presently 27% of Turkey's land is occupied by the forests due to the severe forest destruction since BC. 3000 (Atalay 2002, Efe 2005). The leading coniferous forests of Turkey are composed of pure and mixed Turkish red pine (*Pinus brutia* Ten.), Stone pine (*Pinus pinea* L.), Scots pine (*Pinus sylvestris* L.), Black pine [*Pinus nigra* subsp. *pallasiana* Lamb. (Holmboe)], Caucasian fir (*Abies nordmanniana* (Stev.) Spach), Turkey fir (*Abies bornmulleriana* Mattf.), Taurus fir (*Abies cilicica* (Ant. et Kotschy) Carr.), Kazdag fir (*Abies equi-trojani* Aschers. et Sint.) (endemic species), cedar (*Cedrus libani* A. Richard) and Oriental spruce (*Picea orientalis* (L.) Link).

Black pine is one of the most common and economically important native conifers in Turkey. Thus, many studies have been conducted in several parts of Turkey and related to the different

characteristics of black pine. Some studies focus on general flora and flora of black pine (Davis, 1965-1985; Davis *et al.*, 1988; Zohary, 1973; Güner *et al.*, 2000; Yücel and Ozturk, 2000; Ozturk *et al.*, 2002). There are several studies on silviculture (Carus and Çatal, 2005), seed transfer, regioning (Atalay, 1977; 1987; 1998; 2002), plant rehabilitation (Ozturk, 1995), dendroecology (Sevgi and Akkemik, 2007), management (Baskent *et al.*, 2005), genetic diversity and variation (Gülçü and Ücler, 2008).

However, few studies deal with ecology and distribution of black pine in Turkey (Yücel 2000, Atalay 2001, Sevgi and Tecimen, 2008, Atalay and Efe, 2010a; Atalay and Efe 2010b).

Materials and Methods

The study is based mostly on field monitoring data and field studies conducted several times in the years between 2000 and 2010. Climatic data obtained for the black pine occurrence areas have been analyzed. Precipitation and temperature according to the elevation zones were determined in the black pine areas. Line transects running north-south directions were applied to several localities to find out the effect of aspect, temperature and precipitation. All other factors such as parent material, soil, vegetation and human effect were examined *in situ* by field studies. Meteorological data have been analyzed in order to determine the effect of climatic factors on distribution of black pine.

Results and Discussion

Ecological characteristics of *Pinus nigra* in Turkey: About 13 million ha of the existing forest lands in Turkey consist of coniferous species. Black pine forests cover an area of 2.5 million ha in Turkey. It constitutes pure or mixed forests in the mountainous parts of all coastal regions and inner parts. Anatolian black pine [*Pinus nigra* subsp. *pallasiana* Lamb. (Holmboe)], grows naturally on large areas in Turkey excluding Eastern Black sea, Eastern and South-eastern ecological regions of Turkey (Atalay, 2002, Oner and Eren, 2008). But in the distribution areas of black pine, the ecological conditions change considerably depending on climatic, topographic and parent material properties. So the density, productivity, floristic composition, site index, geographical variation, silvicultural and harvesting properties of the black pine show different aspects according to climatic regions. On the other hand, black pine has several geographical variation and subspecies due to the fact that it occurs on the large areas. These conditions result in the formation of local subspecies within the short distances in the natural occurrence areas of black pine.

Floristically, black pine occurs within the Euro-Siberian, Mediterranean and Irano-Turanian floristic regions of Turkey. Ecologically, black pine grows in habitats ranging from subhumid to semiarid climatic conditions, and all parent materials/rocks. It occurs naturally on a wide range of soil types and textures. Topographically, it commences near the sea level of the middle Black sea coast and continues as high as 2000 m in the mountainous areas. The distribution and productivity of black pine are determined by

ecological factors such as, climate, parent material, topography, anthropogenic factors and floristic composition and competition in Turkey.

Ecological factors and Anatolian black pine -

Climate: Anatolian black pine grows in the mild-humid climate covering the coastal belt of Black sea, including Black sea coastal area of Thrace region, and cold and humid climate prevailing on the mountainous areas of the Northern Anatolia. Marmara climatic region that is transitional climate between Black sea climate and Mediterranean climate, and the Backward region of Black sea characterized subhumid-semiarid climate (Fig. 1).

Anatolian black pine occurs on the oro-mediterranean zone climatic conditions covering the upper part of mountainous areas in the western part of Aegean region and Taurus mountains in the Mediterranean phytogeographical region. Meanwhile, continental climate of the inner Anatolia is the other occurrence areas of the black pine. Semi continental climate prevailing in the Lake district (Burdur, Isparta) and the inner part of the Teke peninsula are also the growing areas of the black pine. Thus, the black pine forests are found in the orobiomes of the Northern, Western, Southern and Inner Anatolian regions, excluding Eastern and Southeastern Anatolian regions and Eastern Black sea subregion. Pure and productive black pine forests are dominant in the subhumid region where the mean annual temperature is 7/8-12°C, the mean January temperature is below freezing point, temperature in July is 18-20°C, while the mean annual rainfall is over 400 mm.

Black pine can regenerate very well on semi-shade environment on which the rate of direct sun radiation and/or light intensity is about 60-70% understorey of the forest. But it is also found on the areas receiveing direct sunlight. These data reveal that black pine can be considered as a semi-shadow tree.

In Turkey, black pine occurs where the mean annual rainfall is more than 1000 mm in the Black sea and Marmara regions, and 400-500 mm in the inner part of Anatolia. Summer rainfall occurs only in the Black sea region and on the north facing slopes of the mountains in the Marmara transitional region covering between the mild-humid Black sea climate and Mediterranean climate, in northwestern Turkey. The northern Anatolia is influenced by the mild and humid air masses, the central Anatolia has a continental, and the southern Anatolia has a Mediterranean climate.

The average annual temperature varies between 12 to 6°C in the natural occurrence areas of black pine. Maximum temperature rises up to 40°C, and minimum temperature drops to as low as -30°C on the higher part of the mountains where black pine occurs (Atalay, 2010; Atalay and Efe, 2010b). The relative humidity during the vegetation period varies between 60-70% in the coastal areas and north facing slopes of the mountains of northern Turkey, and 20% in the inner part of Anatolia. Indeed, the germination of the black pine seeds are better on the mineral soils receiving direct sun radiation. Foggy habitats and shade areas prevent the

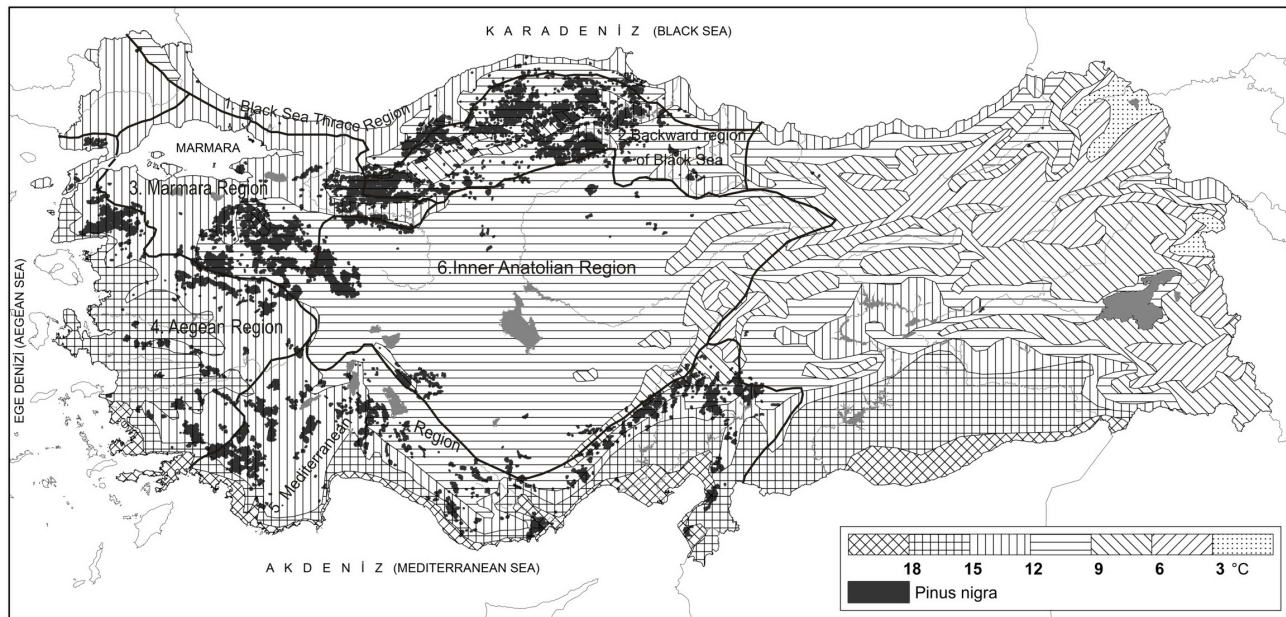


Fig. 1: Annual average temperature and occurrence areas of Anatolian black pine (*Pinus nigra* subsp. *pallasiana*) in Turkey

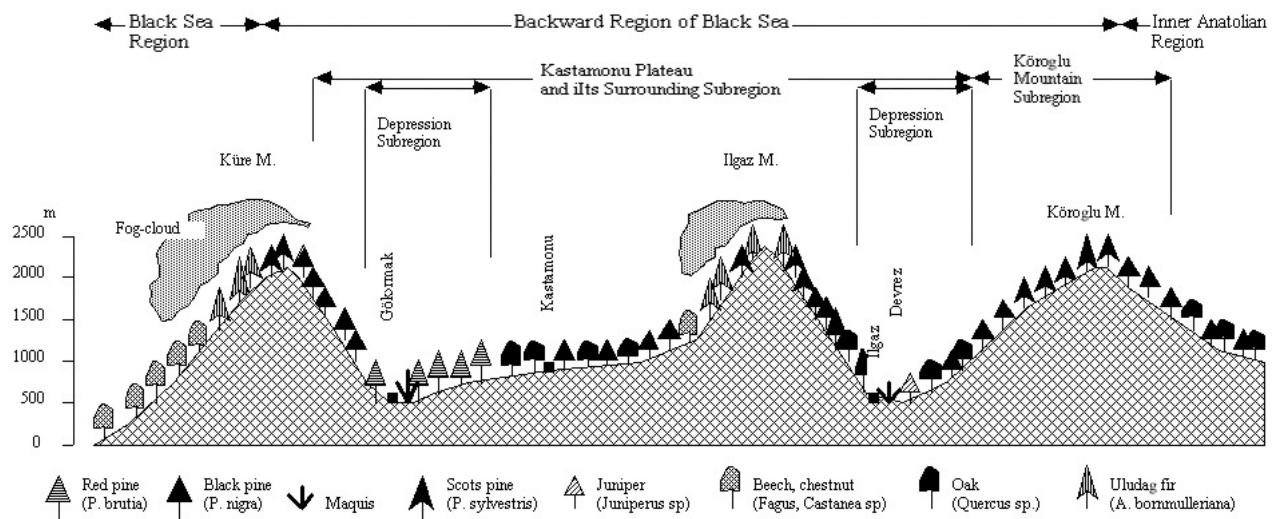


Fig. 2: Regions and subregions of Anatolian black pine between Black sea region and inner Anatolia

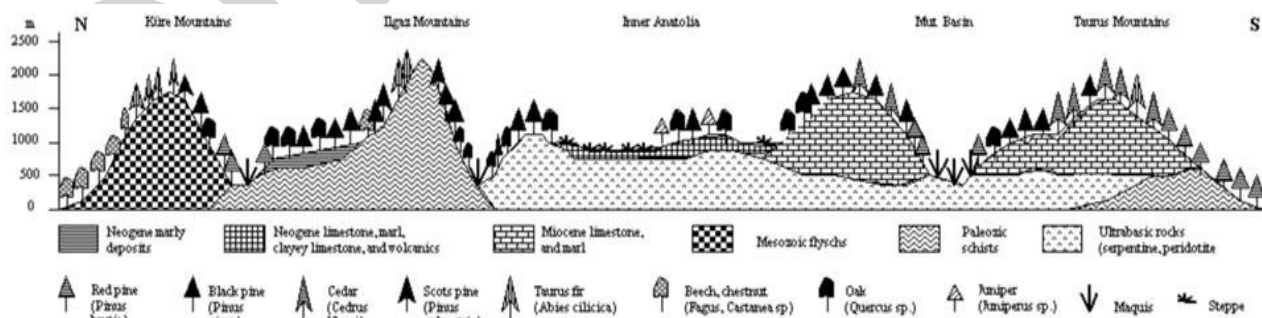


Fig. 3: Vegetation profile and geological cross section in the north-south direction of Anatolia

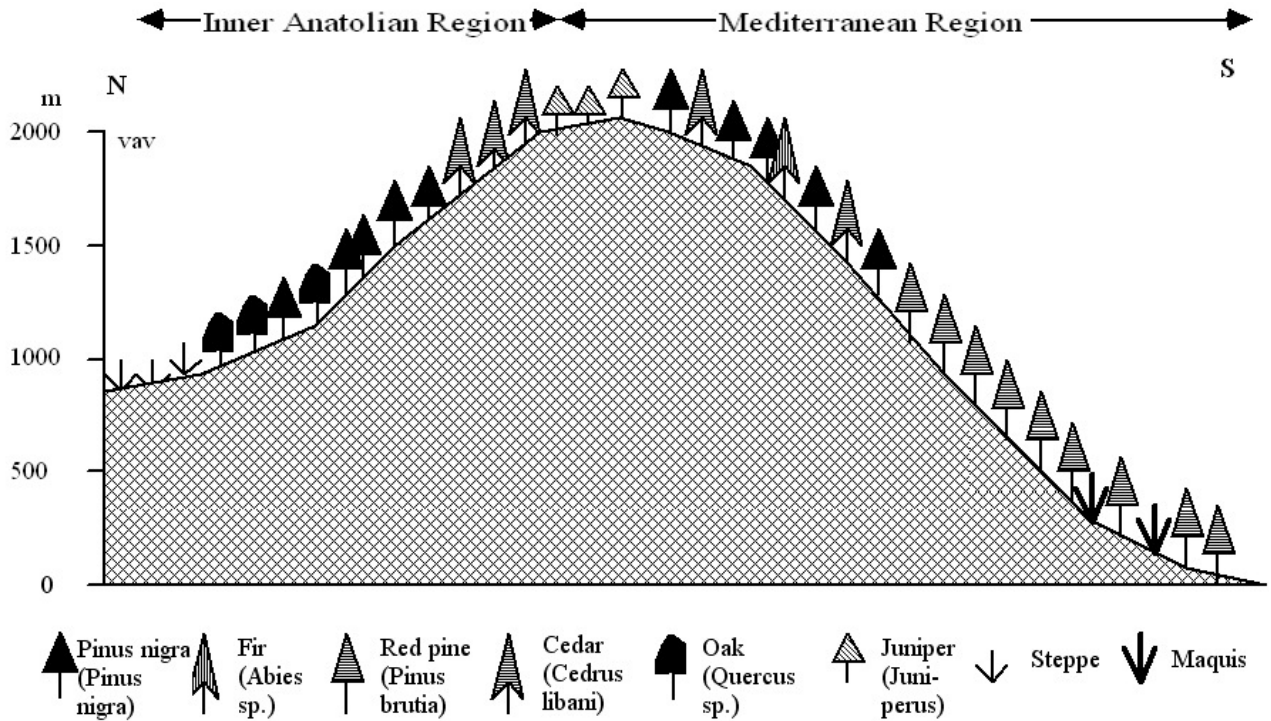


Fig. 4: Vegetation profile between Mediterranean region and Inner Anatolia

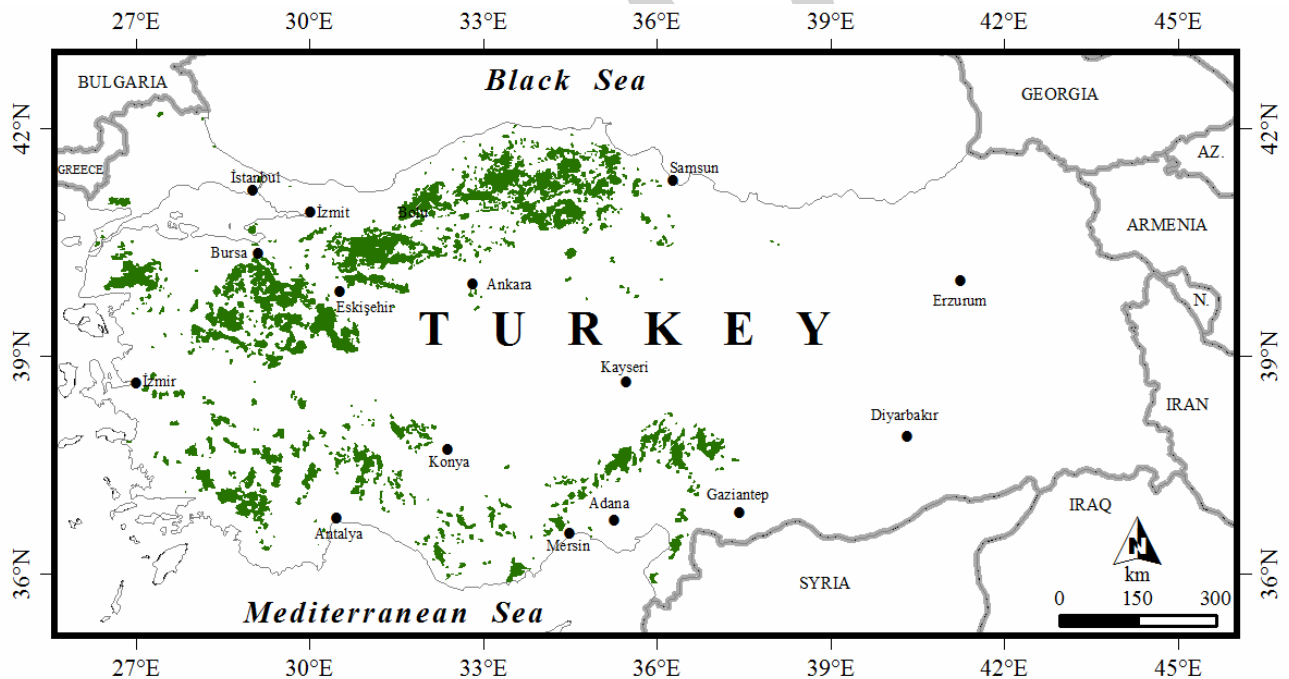


Fig. 5: Distribution of Anatolian black pine [*Pinus nigra* subsp. *pallasiana* Lamb. (Holmboe)], in Turkey

germination of the seeds. It can be stated that subhumid-semiarid continental areas offer the optimum environment for the growth of black pine and productive forests existing in the areas more than 1000 m of the Kastamonu plateau, north facing slopes of Alacam mountain (Boydak *et al.*, 2002, Eruz, 1984) and Kaz mountains (Sevgi, 2003; Sevgi and Akkemik, 2007; Sevgi and Tecimen, 2009; Atalay and Efe, 2010b) in the Marmara transitional region and the

high south facing slopes of the Taurus mountains (Efe, 1998; Sevgi and Tecimen, 2008).

Topography: The main natural occurrence areas of the black pine are determined considerably by the altitude, aspects/exposure, inclination and the direction of the mountain ranges. As a general rule, black pine forests occur notably in the orbiomes changing between 400-1800 m elevations. This altitude changes between

400-1400 m in the coastal belt of the Black sea region, 800-1800 m in the backward region of Black sea, and Aegean and Marmara region; 1000/1200-1800 m in the Taurus mountains in the Mediterranean region and 1200-1600 m in the Inner Anatolian region.

Exposure factor also determines the growing areas of black pine considerably. The lower boundary of black pine is about 200 m in the north and 750 m in the southern slopes of the Kaz mountains, in northwest of Aegean region. Black-pine forests occur extensively on the north facing slopes of Kaz mountains.

But black pine trees are rarely seen on the north-facing slopes in the coastal belt of the Black sea region. This is related to the formation of fogs under which broad leaved deciduous forests. Accumulated dead organic matter on the soil surface and diffuse radiation prevents considerably the germination of the black pine seeds. While the northern slopes of mountains in the Marmara, Aegean and Inner Anatolian region are much more humid than that of the southern slopes. Thus, black pine forests start on both slopes at the lower level but productive stands are found on the north facing slopes (Fig. 2 and 3).

On the other hand, the deep and wide depressions or canyons create not only humid habitats with rich biodiversity, but also the formation of different geographical variation of black pine because the humid air mass of Mediterranean sea goes along the deep valley towards the inside of the coastal belt. For example, the productive black pine forests occur in the Göksun and Esen valleys in the eastern Mediterranean region as this valley receives humid air and form a different habitat for black pine forest (Atalay and Efe, 2010b).

On the other hand, deep and wide tectonic-karstic depressions, produce a different habitat of the encircling higher areas due to the temperature inversion. The bottoms of the depressions such as Simav graben in the northwest of Aegean region, karstic depressions in the west part of the Akseki town in Taurus mountains, Ovacik depression in the middle part of the Aegean region, Inegöl depression (200 m asl) in the Marmara region black pine is found resistant against the colder temperature than red pine.

The inclination degree and different geomorphic sections of the slope form different habitats in terms of the growing and/or productivity of black pine. As a general rule, it can be said that poor black pine stands are common on the steep slopes, while good stands are widespread on the slightly inclined surface of the slopes and the well drained flat bottom lands.

The wide and deep depressions found in interior part of the mountainous areas, form semiarid habitat due to the lee side of precipitation and/or rain shadow areas. Therefore, the depressions in the backward region of Black sea and Mediterranean region like Mut basin is the drier habitat than that of the surrounding areas on which dry forests and shrubs are widespread (Efe, 1998; Efe and Atalay, 2010b).

Thus, altitude, exposure, depressions and the inclination degree of the slopes produce different habitats for the growth of black pine forests, so these topographic factors are responsible for dividing into subregions within same region. On the other hand, interceptions of the fronts by the mountain ranges like Taurus and those Northern Anatolian mountains affect to great extent the distribution of precipitation and temperature. Namely, the southern slopes of Taurus mountains intercept mostly the air masses coming from Mediterranean sea, and the northern slopes of the Northern Anatolian mountains allocate the fronts originating from Black sea. These slopes which receive abundant rain are the natural occurrence areas of productive black pine stands.

The lower boundary of black pine on the north facing slopes is lower than on the southern slopes due to abundant rainfall. For example, black pine occurs within the broad-leaved deciduous forests along the coastal belt of the Black sea and pure stands of black pine forests are found at 1300-1600 m in the direct sun radiation areas in the northern part of the Northern Anatolian mountains (Fig. 2). It begins at an altitude of 200-400 m on the north facing slopes in the Marmara transitional region. The black pine occurs as relict stands at Kasatura, Çilingöz and Igneada in northern slopes of Yıldız mountains in Thrace region. It can be stated that starting level of black pine is lower on the north facing slopes than south facing slopes. On the other hand, the upper limits of black pine which are found in the north is lower than that of the southern part of Anatolia. It forms pure stands at high elevations between 1400-1600 m in the northern Anatolia. Scots pine (*Pinus sylvestris*) covers the upper parts of the mountain slopes up to 1700-2000 m (Atalay, 1977). While the upper boundary of black pine rises up to an alpine-subalpine area at the elevations of 800/1000-1200 m in the southern part of Anatolia.

Dense fog prevents the growth of black pine (Atalay, 2001; Atalay and Efe, 2010b). The productivity of the northern slope is higher than that of the southern slopes due to the aridity. On the other hand, the productive stands are generally found within the middle part of forest zone. Because high temperature leads to an increase in respiration, most of the biomass that produced during the day is consumed during the night by respiration (Atalay and Efe, 2010b). Biomass productivity decreases on the upper parts of the mountains due to the low temperatures.

Parent materials and soils: First of all, it can be stated that there are no strong relationship between the parent materials and the distribution of black pine. Importance of the parent material in the growth of black pine depends mostly on weathering degree, plant nutrients and the circulation conditions of the air and water in the soil and parent materials. Soft and well weathered parent material supports the development of vertical root systems. Poor black pine stands occur on the less weathered parent material such as serpentine-periotite and acidic rocks composed of lahar, volcanic tuffs and sands and compact marly areas. Lateral root system develops especially on hard and less weathered serpentines and

marly deposits which prevent considerably the growth of black pine. But good black pine stands are found on deeply weathered serpentine parent materials in Pos (Karsanti, Mediterranean region), Dirgine, Camiyani localities (Black sea region).

The cracked and fissured limestones of Mesozoic and Palaeozoic era support the formation of pure and productive black pine stands due to development ability of roots along the cracks (Atalay and Efe, 2010b; Atalay, 2006). Flyschs and colluvial deposits composed of fine materials and well weathered gneiss sustain the formation of the good black pine stands due to the fact that black pine trees develop deep vertical root systems.

As to the soil properties, black pine forests are found on the spodosol, alfisol, mollisol, entisol and inceptisol. Soil properties vary depending on climate, topography, parent material and land degradation, especially erosion process. In the Black sea region acidic soils with rich organic content are common. Reddish Mediterranean soils are widespread on the karstic lands of Aegean and Mediterranean regions. These soils occur along the thin cracks and between the layers of limestone on the steep slopes. In the interior part of Anatolia, alkaline soils having calcium carbonate accumulation in B horizons are common. Soil having A and C horizons are found under the dense forests areas which are found on the slightly undulating surfaces. Soil is important factor in the regeneration process, the germination of the seeds and the growth of the young plants. After young stage, the roots of plants begin to develop within the parent materials. So that the feeding and/ or uptaking of the nutrients and the growing rate of the trees depends on the physical and chemical properties of the parent materials (Atalay and Efe, 2010b).

Vegetation composition: Black pine forests are found not only as pure stands but also mixed forests composed of humid/hydrophytes, shrubs and herbaceous species and xerophytic species according to the climatic conditions and habitat properties. Black pine forests can be divided into ecoregions depending on floristic composition of the stands. Namely black pine existing within fir and oriental beech can be considered as a humid forest. Competition ability for light of the black pine is lower as compared with beech and fir trees. The forests consist of cedar (*Cedrus libani*), Taurus fir (*Abies cilicica*) and black pine occur together in the same locations on the Taurus mountains. *Pinus nigra* and red pine mixed forests are found on transitional zone between Lower Mediterranean and Oro-Mediterranean zone.

The forests with Scots pine (*Pinus sylvestris*), oriental beech (*Fagus orientalis*), fir (*Abies bornmulleriana*) and black pine imply the transitional belt extending between the subhumid and humid forest region in the northern part of Anatolia. In the mixed forests, black pine and fir grows in the foggy areas and the understory of these forests, so in the mature stage of the forests fir become as dominant trees, due to the competition.

Mixed forests composed of *Fagus orientalis*, *Abies bornmulleriana*, *Pinus sylvestris* and *Pinus nigra* occur only in humid

habitats. Shaded parts of forest floor are the main regeneration area of *Abies* sp, and sunny areas create favorable conditions for the regeneration of the *Pinus sylvestris* and *Pinus nigra*.

Pinus nigra and *Quercus vulcanica* forests which are found in the Sultan mountains, southwest of Inner Anatolia and Davraz mountain in the lakes region characterize the subhumid environment (Atalay and Efe, 2010b).

In the semiarid areas of inner Anatolia, black pine stands composed of oak species, Laurel Rockrose (*Cistus laurifolius* L.) and some xerophytic shrubs, black pine and *Cistus laurifolius* mixed stands are widespread. These communities reflect the existence of the semiarid environment. Here pure *Cistus* sp. cluster, mostly occur on the siliceous parent materials such as gneiss, volcanic tuff and sands, is the main indicator of natural occurrence areas of Anatolian black pine. But oak species form an understory layer of black pine in the tectonic depressions of Backward region of Black sea.

The herbaceous species also indicate the site index situation of black pine forest. That is the black pine stands which are associated with *Vaccinium* sp., *Rhododendron* sp., and some subalpine herbs imply the humid habitat.

The pure black pine forests and productive stands are common in the northern part of the Taurus mountains and the southern section of Marmara region such as Kaz mountains, Alacam mountains, in the western part of Beysehir lake and the backward part of Black sea region.

As a result, ecological tolerance of black pine is wide since it grows well in the humid, subhumid, semiarid climatic types, all parent materials and different landforms. This is related to special genetic properties of it. Therefore, climatic and topographic properties in the natural distribution areas of black pine lead to the formation of least 15 different geographic variations of black pine. These situations are also responsible for the endemic species of black pine such as The Ehrami black pine [*Pinus nigra* Arnold. subsp. *pallasiana* (Lamb.) Holmboe var. *pyramidata* (Acatay) Yaltirik] and Ebe black Pine [*Pinus nigra* subsp. *pallasiana* var. *seneriana* (Saatcioglu) Yaltirik]] (Acatay, 1956; Alptekin, 1986; Alptekin, 1987; Yücel, 1995; Atalay and Efe, 2010b).

Anthropogenic factors: Historical records and contemporary research suggest Anatolia had 60-70% forest cover and 10-15% steppe around 2000 BC (Atalay, 1992). The forest area has declined to 26% as a result of over-grazing, over-cutting, fires, spread of agricultural lands, wars, etc. and steppe has increased to 24% in the intervening 4,000 years (Louis, 1939; Efe, 2005, Colak and Rotherham, 2006, Ozturk, 2002). Below 1500 m, forests are strongly affected by subsistence agriculture and overgrazing although some ecologically significant stands remain at those elevations. The distribution of black pine also decreased parallel to other species in Turkey.

It can be stated that the semiarid part of the Anatolia is termed as a fragile ecosystem and/or habitat. Black pine belongs to

the dry forest which is characterized by sparse and low productivity, and the understory vegetation is mainly composed of steppic herbaceous species. The degraded black pine areas have been generally occupied by the steeper vegetation. Presently, black pine clusters are found only on volcanic cones such as Mt. Melendiz, Mt. Hasan, Mt. Sundiken in the northwest of Turkey, in the vicinity of Yozgat city and the plateaus located in the northwest part of Inner Anatolia. Remaining areas are termed as an anthropogenic steppe. Steppe vegetation and/or ecosystem is found in the Konya and Tuz Golu (salt lake) basins, and the plateau surfaces extending from the Tuz Golu (salt lake) and Eskisehir plain.

Distribution and natural occurrence areas of black pine forests in Turkey: Anatolian black pine forests occur in the transitional region between subhumid and continental semiarid climates in Turkey. It starts near the coastal belt of the western part of the Black sea geographical region and climbs up to 1500-1800 m in the northern part of Anatolia and 2000 m in the Taurus mountains and western mountainous area of Anatolia. It starts 1400 m and rises up to 1800-2000 m in the Inner part of Anatolia within which semiarid climatic conditions prevail (Fig.4).

Pure black pine stands are common on the southern parts of the Black sea and Marmara transitional, Aegean regions and the plateau surface of Western Anatolia. It constitutes forest stands which are pure or mixed with Scots pine, fir (*Abies bommulleriana* Mattf.) and oriental beech (*Fagus orientalis* Lipsky) on Northern Anatolia and with Taurus fir (*Abies cilicica*), cedar (*Cedrus libani*) on the Mediterranean region of Turkey. Black pine forests are only found on the northern slopes and the upper part of the Northern Anatolian mountains and backwards of the Black sea region. In Taurus mountains *Pinus nigra*, *Cedrus libani* and *Abies cilicica* mixed forest are widespread. Shrubs and understory species such as *Quercus cerris*, *Q. pubescens* Willd., *Cistus laurifolius* L. may be included in some localities (Atalay, 1994; Atalay and Efe, 2010b; Sevgi and Tecimen, 2008).

Ecologically, black pine grows on all parent materials, alkali and slightly acidic soils, but best growth occurs on sites with well and deep weathered parent material (Atalay and Efe, 2010b). Productive black pine forest are found in subhumid-semiarid areas receiving humid air mass coming from the seas. The poor and/or lowest productive stands occur in the humid and foggy part of Black sea region, the highlands of Lake Aci and Lake Burdur, on the marly deposit and clayey limestones, rainshadow of Upper Göksu Basin subregion (Atalay and Efe, 2010b).

Black pine forests are divided into six regions depending on the ecological properties.

Coastal region of Black Sea and Thrace: This region encompasses the north facing slopes of the middle and western parts of the Black sea mountains. The influence of Black sea climate forward to the inland along the wide valleys. Black sea region covers the northern and upland part of the Kure mountains and

Akcakoca mountains comprising the western part of the Northern Anatolian mountains. This region is under humid, cool and cold climatic conditions and forms ecologically the orbiomes of Black sea region. The mean yearly temperature ranges between 8-10°C. During winter season temperature goes below the freezing point and during summer the temperature is between 16-18°C. The mean annual rainfall is more than 1000 mm. Rainy periods covers all seasons and maximum rainfall occurs during the fall and winters. There is no water deficiency during the vegetation period. Relative humidity is over 60% during the vegetation period, because there is continual air flow coming from the Black sea. Fog is common in the northern slopes of the mountains due to the rising of the cool and rich moisture of the air mass coming from the Black sea.

Black pine in the Çitdere basin is the leading humid forest area found at an elevation between 1150-1600 m on the slope facing south. Here, black pine called Camiyani grows on the deep weathered serpentine rocks. The depressions such as between Azdavay-Cide and Filyos valley are influenced with humid air mass coming from Black sea are the natural occurring areas not only for broad-leaved deciduous forests but also coniferous forests. Here, black pine with pure and mixed stands in the lowland part of depressions. One of the leading black pine stands are found on the well weathered serpentine in the Dirgine depression.

In the coastal belt, black pine is found between Zonguldak and Çatalzeytin towns. Indeed black pine clusters are seen at an elevation of 500-600 m, north of Çatalzeytin on the northern slopes of Küre mountains and the coastal area of Çatalzeytin coast. First area is found in the abandoned agricultural field, and last one is related to the broad-leaved forest area, here black pine is associated with *Laurus nobilis*, *Pinus brutia* and *Carpinus orientalis* and *Fagus orientalis*. Between Cide and Inebolu towns leading black pine stands are seen in the vicinity of Doganyurt, a coastal town of Black sea coast.

Backward Black sea region: This region is located between the southern high slopes of Küre, Canik mountains in the north and southern upper slopes of Köroğlu mountains in the south. It starts in the eastern section of Marmara geographical region roughly and continues as far as the east of Niksar town, north of Erbaa-Niksar tectonic depression, in the southern part of Canik mountains. In other words, the region is the transitional region or zonoecotone between Black sea humid climate and the inner Anatolia semiarid climate.

The mean annual temperature ranges between 10 and 6°C, summer temperature is higher and winter temperature is lower than that of the Black sea region due to the semi continental effects (Atalay, 2010). The amount of mean yearly rainfall ranges between 600 mm to 1200 mm. Sometimes during the summer season precipitation occurs, and fog rarely takes place on the north facing slopes. The relative humidity is over 40% during the vegetation period. In this region, black pine starts at an altitude of 600-800 m on

the slopes of valley and tectonic corridors and rises up to 1800-2000 m. The bottom part of the tectonic corridor and valleys are covered by the poor *Pinus brutia* stands, juniper and oak communities due to the semiarid climatic conditions. The pure and productive *Pinus nigra* forests are found on the Kastamonu plateau and the northern slopes of the Kaz, Alacam and Ilgaz mountains (Atalay and Efe, 2010b; Boydak *et al.*, 2002). Mixed forests occur along the valley and in foggy habitats which are found on the northern slopes of mountains. *Pinus nigra-Abies bommulleriana*, *Pinus nigra-Pinus sylvestris-Fagus orientalis*, *Pinus nigra-Fagus orientalis*, *Pinus nigra-Pinus sylvestris*, *Pinus sylvestris-Abies bommulleriana* mixed forest stands occur on the north facing slopes in the southern part of the Arac district (Kastamonu). *Abies bommulleriana-Pinus nigra-Fagus orientalis* mixed forest and/or communities are only found on the slopes where fog forms. The higher part of Kastamonu plateau (1300-1500 m) is the most productive black pine forest areas. Black pine trees up to 35-40 m tall, with a 3 m radius and more than 300 years old are found on a hill that is located between the Araç and Daday districts (Atalay and Efe, 2010b) (Fig 5).

One of the leading pure black pine forests is found in the Mudurnu-Göynük depression on which semiarid-subhumid climatic conditions prevail. Pure black pine stands also occur on lower part of the Kibriscik plateau, and especially on the northern slopes of the Cuma valley, at an elevation of 800-100 m, in southern part of Kibriscik town. The area extending between Ladik and Suluova depression is covered by mostly pure black pine forests. The edge of Mengen and Eskipazar depressions, middle west of the region, contain almost pure black pine forests.

Black pine forests commence at an elevation of 600-800 m on the upper edges of the depressions and rise up to 1600 m in the Kastamonu plateau and its near vicinity. The biomass productivity of the black pine increases in high as 1400 m, after that it decreases due to decrease of temperature. Good stand black pine forests occur in the western part of Kastamonu plateau. Here in the vicinity of Karkalkmaz locality black pines having 45-50 m tall and 220-310 cm diameter are established at an elevation of 1400 m, on the sand stone, siltstone and limestones.

Black pine trees occur within the scots, fir and beech forests where humid-subhumid climatic conditions prevail on high lands and on the slopes facing north. In fact, black pine forest beginning 600 m in Boyabat depression is replaced to black pine-scots pine forests over 1100 m in the southern mountainous areas. In the highland of northern part of same depression black pine is found as a small cluster within fir, beech and scots mixture forests.

From Kastamonu to Ilgaz mountains depending on the increase of altitude black pine forests mixed with beech, scots pine, oak are found around Kastamonu, Ilgaz mountains, Tosya depression, Iskillip and Canik mountains.

Marmara region: This region occupies the Biga peninsula in the west, and the rivers water- shed basins connected to Marmara sea. This region continues Demirci, Simav and Murat mountain in

the south, Uludag-Domaniç mountain range in the SE. This region is the transitional region between Black sea and the Mediterranean climatic regions. Ecologically, this region is different from both Aegean, Mediterranean and Inner Anatolian regions.

The altitude of region increases from north to south. In fact the mountainous area in south rises up to 2000 m (Akdag 2009 m, Mt. Simav 1801 m, Mt. Egrigöz 2181 m, Mt. Murat 2312 m, Mt. Ulu 2543 m. Mt. Domanic). These mountainous and highlands areas are dissected by the rivers flowing into Mediterranean sea. There is a tectonic depression on which Lake Ulubat and Lake Manyas are located between Bursa and Gönen cities.

Another topographic property of the region is existing isolated mountains in the mountain ranges. For example, there are many mountains called Kaz, Eybek, Katran, Gürgen, Asar and Kalkim mountains in the Kaz mountain range. Pure and productive black pine forests are widespread on the northern slopes of Kaz and Alacam mountains.

There is a close relationship between productivity and the altitude in Alaçam mountains. Black pine forests with good stand class are found between 1200-1400 m (Eruz, 1984). Here, Ist and IInd site index forests appear between 1000-1400 m as compared with other altitudinal level. This is related to decrease in temperature. Moreover good and/or productive black pine forests are seen on the slope changing between 1-3% . IIIrd and Vth site index black pine forests are widespread where slope degree changes between 59 and 100% (Eruz, 1984). This explains that the lower slopes have good and/or productive black pine stands

Aegean region: This region covers the western part of Anatolian geographical region and continues upto the plateau area of the eastern part of Aegean region. Ecologically, this region is found between the northern limit of cedar forests of Taurus mountains in the south and the southern natural occurring areas of oriental beech forest of the Marmara region in the north. The orobiomes and/or mountains fit the horsts extending between the grabens such as the Gediz, Buyuk Menderes and Kucuk Menderes rivers. The upper part of *Pinus brutia* forests are replaced by black pine in the mountainous areas. It starts at about 1000 m in the south and 800 m in the north due to lower temperature. The upper boundary of black pine is 2000 m. Main occurring areas of black pine are the Simav, Boz and Aydin mountains and the northern part of Mentese mountains (Fig. 2). There is a disimetric distribution between the north and south facing slopes. Namely, the lower boundary of black pine is about 700-800 m on the southern slopes, and 400-500 m on the northern slopes of the Aydin mountains. Black pine forests are pure structure in general. But along the valley on the northern slopes, Anatolian chestnut (*Castanea sativa* Miller) clusters occur (Atalay and Efe, 2010a). In the eroded areas, metamorphic schists containing gneiss and micaschists and quartzitic schists are exposed as a bare land. The regeneration of the forest on this kind of land is too difficult. For this reason these areas are devoid of any forest cover. In other words, degraded areas on the schists can be

considered as a desertification areas due to unfavorable conditions and poor vegetation cover.

Black pine forest commence at elevation of 800-1000 m on the south slopes, and 500-600 m on the north slopes of the mountains and attain 1800-2000 m in the inland part of the region (southern slopes of Murat mountains, eastern part of Aegean region). Lower belt of black pine forests are composed of some maquis elements and especially oak species in the inland part of Aegean region.

Leading black pine forests appear on the Boz mountains and the eastern part of Aydin mountains; productive black pine forests are common on the Yilanli mountain, north of Mugla city. Indeed this area receives at least 1000 mm rainfall annually. Floristic composition of black pine forest also reflects its biomass productivity and/or site index. For example, black pine forests with *Cistus laurifolius* indicate the existence of dry or low productive black pine forests, while the forests with underground fern are in good stand.

Good black pine stands are found on the northern slopes, and the high slopes facing-south, but poor stands appear on the lower south slopes of the mountain except for Yilanli mountain in the south.

Mediterranean region: Mediterranean region covers an area extending Köycegiz district in the west and the Boz mountain, Honaz mountain, Dazkiri district, the southern slopes of Sultan mountains in the northwest, the higher areas of middle Taurus mountains in the north and Nur mountains in the east. Shortly, the Mediterranean region covers almost all part of the Mediterranean geographical region of Turkey. The Mediterranean region containing black pine forest extends between the eastern part the Gulf of Iskenderun in the east and southwest part of the Taurus mountain range. Extensive black pine forests are found in the southern part of Mentese mountains, in northern part Gulf of Antalya and the upper part of the middle Taurus especially Taseli plateau and the upper watershed basin of Ceyhan and Seyhan rivers. *Pinus nigra* forests in the Mediterranean region occur in orobiomes of the Taurus mountains.

The climate of the orobiome of Mediterranean region is characterized by cool-cold and snowy winters and semiarid, cool summers. The mean annual temperature of this orobiome ranges from 10°-12°C to 6-7°C, with a maximum temperature of 40°C and winter temperatures vary between 0°C-4°C and -2,-3°C. The mean annual rainfall is more than 600 mm, and south facing slopes receive more than 2000 mm rainfall. The relative humidity is more than 60 % during the summer season depending on humid airflow coming from the Mediterranean sea.

The stands of pure black pine are found on the Mentese mountains, northern and eastern upper areas of Antalya Gulf and upper watershed basin of the Ceyhan and Seyhan rivers. Mixed forests composed of *Cedrus libani*, *Abies cilicica* and *Pinus nigra* forests occur between 1000-2000 m on the south facing slopes of the Taurus mountains (Atalay, 2008; Atalay and Efe, 2010b).

Karstic lands provide suitable habitat for the growth of not only red pine and cedar, but also black pine. Because seeds germinate easily within the cracks of limestones and the roots of the plants follow the seepage water along the cracks. Roots grow up to 1 m within a vegetation period.

Productive black pine forest occur on the eastern part of Bolkar mountain and Sogut plateau, western part of middle Taurus and southern part of Lake Beysehir. It constitutes forest stands which are pure or mixed with Taurus fir (*Abies cilicica*) and Lebanon cedar (*Cedrus libani* A. Rich.) and juniper (*Juniperus* sp.) on the northern slopes of the Western and Southern Anatolian region. The upper part of the Taurus mountains is generally occupied by juniper (*Juniperus foetidissima* Willd, *Juniperus communis*, *Juniperus excelsa*). This is related to the clear cutting of the Lebanon cedar and black pine forests by Yoruk (nomadic) tribes. The birds are usually responsible for the dispersal of the juniper seeds.

Pure and mixed black pine forests mostly with cedar are found between Nur mountain in the southeast, and in the vicinity of Tufanbeyli in the east, and continue along the Taurus mountains and reach to Aegean region. The productivity of pure black pine is found on serpentine rock at elevation of 600-700 m in the southern part of Nur mountain. Black pine is composed of oriental beech (*Fagus orientalis*) in the vicinity of Andirin district. In north, it is replaced by mixed forest with cedar and Taurus fir, and pure black pine forest toward inner section in the eastern part of Mediterranean region. Good black pine stands occur in the northern part of Saimbeyli town, and climbs up to 2400 m at the Dedebehi locality between Turfanbeyli and Saimbeyli towns. This locality is the highest point of black pine in the Anatolia. Other good stands are seen at the Cödden locality in the upper basin of Ceyhan river, and in Karsanti (Pos) district in the northern part of Çukurova.

Black pine forests are found as clusters on the southern edges of Ala and Bolkar mountains in the inner section that does not receive the humid air of Mediterranean. Here, black pine climbs up to 2000 m in the vicinity of Çamlıyayla town.

In the Göksu basin to be characterized the semiarid part of the Mediterranean region, black pine forests are found as cluster and dry forests on the compact marly and soft limestones formation. Most of the black pine trees are seen as an umbrella form.

The widespread areas of the black pine forests occur between Abanoz locality in the north part of Anamur and Dedegöl mountains in the western part of Lake Beysehir. Best productive and good stands of black pine forests are seen in the Islıbuca locality, west of Lake Beysehir and the southern slopes of Dedegöl mountains. In the karstic lands in the western part of Lake Beysehir, black pine is composed of cedar and Taurus fir. Black pine trees are only seen on sunny and/or direct sun radiation areas of the karstic lands.

Black pine forests occurring between Sütçüler town and Lake Egirdir grow on the serpentine areas. Here, poor stand black pine forests appear on the steep slopes, but good ones are seen on

the lower slopes and along the valleys. In the northern part of the Sütçüler town the dejection fans with coarse limestone gravels are partly covered by black pine clusters.

The Gölhisar depression and its surroundings areas are located in the southern part of Teke peninsula form a different and/or special environment. Here the Sögüt depression containing neogene soft limestone and marly deposits is covered by red pine and oaks, and black pine forests are commence to see after 700-800 m and reach to 2000 m. Good black pine stands are found on the mesozoic cracked limestone, while low productive stands are common on the marly deposit and clayey limestones. The good and productive black pine stands with cedar trees are found in the upper part of Esen canyon valley due to the fact that the humid air coming from the Mediterranean sea cause suitable habitat for the growth of black pine

Inner Anatolian region: Inner Anatolian ecologic region covers most part of the Inner Anatolian geographical regions. The region is bounded by Murat-Sandikli mountains in the west, eastern part of Kütahya province, northern slopes of Taurus mountains in the south, Uzun plateau-Tahtali mountain ranges called Anatolian diagonal in the east, and the southern high slopes of the Northern Anatolian mountains. This region covers the interior part of Anatolia and is surrounded by mountain ranges. Closed basin such as Lake Tuz and Konya basin are found in the southern part of the Inner Anatolia. Continental semiarid climatic conditions characterized by cold and snowy winters, rainy springs and dry and hot summers prevails in this region. Mean annual temperature is about 8-10°C, summer temperature is nearly 18-20°C, winter temperature goes below freezing. When very cold air mass coming from the Eastern Anatolia occupies Anatolia, temperature drops as low as -30°C.

The average annual rainfall varies between 400-500 mm, but it decreases to 200-300 mm in some years. Relative humidity is lower than 30% and on some days of August this figure decreases to as low as 1 to 2%. This situation increases the amount of evapotranspiration. For this reason, the natural vegetation occurring on lowlands of the Inner Anatolia is characterized by steppe vegetation. Oak clusters are found at the elevations over 1200 m, and *Pinus nigra* forests commence at an altitude of 1200-1300 m rising up to 1800-2000 m (Fig. 2).

Black pine forests in the Inner Anatolian region are sparse, average height is less than 10 m and ground vegetation is composed of herbaceous plants and shrubs. Most of black pine stands are in shrub form where productivity is very low (Dagdas, 1998; Atalay and Efe, 2010b). Good stands for the Inner Anatolian conditions are found on the Yazilikaya plateau, and the southern slopes of Sundiken mountains, in North western inner Anatolia. Major part of the black pine forests have been completely destroyed, and occupied by steppe vegetation. It can be stated that black pine forest of the Inner Anatolia can be classified as dry forest.

Leading oak, black pine and pure black pine with understory *Cistus laurifolius* are found in the Yazilikaya plateau, Köroglu Gate between Ankara-Afyon highway and its vicinity, the edges of Sundiken mountains northwestern of Inner Anatolia, southern part of Ankara (Beynam forests), Yozgat locality in the vicinity of Yozgat city, Sultan mountains and its southeast extension, southwestern part of Anatolia and southeastern part of Anatolia as a small cluster. Best productive black pine forests appear on the northern slope of Sultan mountains and southern high slopes of Sündiken mountains. It can be stated that black pine clusters are seen on the highlands encircling Inner Anatolia

The optimal altitudinal range of black pine is between 800 to 1500 m in most parts of Turkey. It is a light-demanding species, intolerant of full shade but resistant to wind and drought. It covers extensive areas on Western Black sea region and is found in few isolated populations in several areas of Turkey.

The results demonstrate that black pine forest grows in three floristic regions: Mediterranean (Aegean and Mediterranean Region of Turkey), Irano-Turanian (Inner and Eastern part of Turkey) and Euro-siberian (Northern part of Turkey). Black pine forests develop well in subhumid-semiarid areas covering the southern part of Black sea region and Marmara transitional regions.

Black pine forests are widespread in the Aegean and Lakes regions. The orobiome of the Taurus mountains in the Mediterranean Region is occupied by *Pinus nigra*, *Cedrus libani* and *Abies cilicica*. Pure black pine forests are rarely found as compared to other regions, but productivity is high especially on the ultrabasic rocks. Poor and/or lowest productive black pine forests growing under the semiarid climatic conditions prevail in the Inner or Central Anatolia. Altitude and exposure are very important factors which affect the growth and distribution of *Pinus nigra* forests.

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