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Research article/Araştırma makalesi

The relationships between growth of *Pinus sylvestris* ssp. *hamata* forests with ecological factors in Central Anatolia

Ş. Teoman GÜNER *[1], Ersin YÜCEL[2]

[1] Research Institute for Forest, Soil and Ecology, P.K.61, 26160 Eskisehir, Turkey
[2] Anadolu University, Faculty of Science, Department of Biology, 26470 Eskisehir, Turkey

Abstract

In this research, relationships in *Pinus sylvestris* ssp. *hamata* (Yellow pine) forests spreading over Türkmen Mountain (Turkey) were investigated between ecological factors. Although a positive relationship was found between site index and altitude and exposure which are among physiographic habitat factors, a meaningful relationship was not found between exposure and slope position (distance from the top edge of the slope). There was a positive relationship between site index and annual rainfall; however, there was not a meaningful relationship between annual average temperature and main rock. A negative relationship was found between site index and B in the litter and humus layer of the forest floor, and a positive relationship N and P in the litter layer was found. The relationship was found site index and Mg and Zn in the needle as positive, it was negative in B. It was determined that there were meaningful statistical relationships between site index and variables of soil horizons. When physiographic habitat factors were evaluated with climatic characteristics and litter characteristics, percentage values of soil horizons variables on the total effect of Yellow pine's maximum height growth was 47.6% in joining grade.

Key words: yellow pine, forest, Türkmen mountain, Pinus sylvestris

1. Introduction

Yellow pine (*Pinus sylvestris* L.) is a tree species which is found in Europe and Asia, between 37º-70º north latitudes and 7º-137º east longitudes (Mirov, 1967). Its habitat includes all northern regions and it has the widest habitat among all tree species. The northest border of the tree is 70º north latitude in Norway. In the south, it spreads out from eastern Asia to Ural mountains and it grows in Russia, Galicia (in Poland), Carpathian Mountains, Yugoslavia, Bulgaria with intermittent existence and it grows between 41º48´-38º34´ N latitudes and 43º05´-28º50´ E longitudes in Turkey (Figure 1). Yellow pine has 5 subspecies and, *Pinus sylvestris* L. ssp. *hamata* (Steven) Fomin. (Yellow pine, Scots pine), which is one of these subspecies, grows in Crimea, Caucasia and Turkey (Richardson, 1998).

Total area of forest in Turkey is 20.763.247 hectares, and in total Yellow pine constitutes 5% of it with a 1.037.751 area (Anonymous, 2001). The Yellow pine is an important tre species both extend of widespread and economic value in Turkey. On the research area which is located between Eskişehir and Kütahya, Yellow pine covers an area of 8.766 hectares. It exists as the only species on 5.821 hectares of the area and survives together with

Yellow pine, beech, oak and trembling poplar within a mixed forest habitat on Türkmen massif. Türkmen mountain is one of the southest points where Yellow pine distributes all over the world.

In this research, identification of relationships between Yellow pine's succession on Türkmen mountain and habitat factors were aimed.

2. Materials and methods

In this research, Yellow pine was chosen as the research material and Türkmen Mountain habitat was chosen as the research area. With the aim of determining the relationships between Yellow pine forests' height growth and edaphic and physiographic features, 48 sample areas were chosen (Table 1); and the materials taken from litter and the trees which were cut, were evaluated via the methods below.

* *Corresponding author* / Haberleşmeden sorumlu yazar: Tel.: +902220222324; Fax.: +902223022232; E-mail: stguner@gmail.com
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Figure. 1. Geographical location of the study area, Turkmen Mountain, Turkey

Sample areas were chosen among areas which were far from road edges, highly trodden areas, unnatural pits and mounds, sharp and rocky slopes and human settlements. These were chosen with same characteristics (Yücel, 1995). Among areas where Yellow pine grows on the massif, 5 altitude steps from north exposure and 3 altitude steps from south exposure were chosen. From each altitude step including 5-7 sampling plots and 48 sampling plots were chosen totally (Table 1). Sampling plots were chosen among the pure Yellow pine stands or Yellow pine-dominated stands.

Table 1. Sampling plots on altitudinal gradients

Altitudinal gradients (m)	Slope	Number of sampling plot	Number of soil sample	Number of forest floor sample	Number of needle sample	Number of tree sample
1200–1300	North	6	6x5=30	6x3=18	6x3=18	6
1300–1400	North	6	6x5=30	6x3=18	6x3=18	6
1400–1500	North	6	6x5=30	6x3=18	6x3=18	6
1500–1600	North	7	7x5=35	7x3=21	7x3=21	7
1600–1700	North	6	6x5=30	6x3=18	6x3=18	6
1600–1700	South	6	6x5=30	6x3=18	6x3=18	6
1500–1600	South	6	6x5=30	6x3=18	6x3=18	6
1400–1500	South	5	5x5=25	5x3=15	5x3=15	5
Total		48	240	144	144	48

In each sampling plot, one soil profile pit was dug, and samples were taken from litter, fermentation and humus layer. Mineral soil horizons were distinguished and genetic soil type of the soil profile was determined (Kubiena, 1953) and 1 liter of soil samples were taken from mineral soil horizons by using a volume cylinder. In order to determine growth relationships, a representative tree of the stand in the upper step of the sample area was cut down and its height was measured as cm and then the tree was cut in to 2 m long parts and thin cross sections were taken from the stem (Yücel, 1999). In order to determine nutritive value relationships, samples were taken from one, two and three aged needles which are in the 3rd sprout circle backwards from the terminal sprout of the tree which was cut for stem analysis.

Cutting the tree and getting the needle samples took place in the first week of October, a period between end of September and beginning of March (Dündar, 1980).

Soil samples were collected by using the volume cylinder and passed through a 2 mm sieve. Then the soil samples were dried at 105 ºC and their dry weight were found. Dry weight was calculated in "g/liter" with ratio of the values which were found, to the sample volume (Gülçur, 1974). Available water was measured by pressure panelled soil humidity determiner equipment, proportion of particle size was measured by hydrometer method of Bouyoucos' (Bouyoucos, 1962); actual acidity was measured by a pH meter with glass electrodes in ½.5 distilled water, N was measured by semi-micro kjeldal method using Kjeltec Auto 1030 Analyzer, electric conductivity was measured by "Conductance Bridge" equipment as miliSiemens/cm using the soil saturation extract at 25 ºC (Jackson, 1962); organic carbon was measured by wet combustion method of Wackley-Black (Wackley and Black, 1934), P was measured by Spectronic 20D spectrophotometer equipment using Bray and Kurtz No.1 method (Bray and Kurtz, 1945); K^+, Na^+, Ca^{2+}, Mg^{2+}, Fe^{2+} and Mn^{2+} was measured by ammonium acetate method, S was measured by turbidimetric method using Spectronic 20D spectrophotometer equipment (Jackson, 1962); K^+ and Na^+ was measured by Jenway PFP 7 flame photometer equipment and Ca^{2+}, Mg^{2+}, Fe^{2+}, Mn^{2+} was measured by Perkin-Elmer 3110 atomic absorption spectrometer equipment, cation exchange capacity (CEC) of the soil was determined by sodium acetate method using Jenway PFP 7 flame photometer equipment (Chapman and Pratt, 1982), B was measured by colorimetric carmin method using Spectronic 20D spectrophotometer equipment (Kaçar, 1994), Cu^{2+} and Zn^{2+} was measured by double acid ($HCl+H_2SO_4$) method using Perkin-Elmer 3110 atomic absorption spectrometer equipment (Perkins, 1970). Forest floor and needle samples' weight were determined after drying for 24 hours at 65 ºC (g/m^2), N was measured by semi-micro kjeldal method using Kjeltec Auto 1030 Analyzer equipment (Jackson, 1962); P was measured by vanado-molybdophosphoric yellow color method using Spectronic 20D spectrophotometer equipment, B was measured by curcumin method using Spectronic 20D spectrophotometer equipment, Ca, Mg, Na, K, Fe, Cu, Zn, Mn concentrations of forest floor samples were performed wet combustion with nitric-percloric acid by using Jenway PFP 7 flame photometer equipment for K and Na, and Ca, Mg, Fe, Cu, Zn and Mn was measured by Perkin-Elmer 3110 atomic absorption spectrometer equipment (Kaçar, 1972); S was measured by turbidimetric barium sulphate method using Spectronic 20D spectrophotometer equipment (Chapman and Pratt, 1982). Fresh and dry weight (24 hours at 65 ºC) of the needle samples which are one, two and three years old were determined. Besides, 100 fresh needles were measured and their average length was found. Quantities of organic substances in needle samples were found by burning the samples by comparing the difference between dry weight and ash weight (Kaçar, 1972).

In order to determine growth relationships, ages of the trees which were cut from each sample area and brought to laboratory were found analyzing the two-meter long cross-sections (Kalıpsız, 1984). The data was evaluated by GAPROG program.

Petrographic identification of the main rock samples were analyzed at General Directorate of Mineral Research and Exploration. Also, relationship between Yellow pine habitat and geological characteristics of the area was investigated using Turkey Geology Map's Ankara section with a scale of 1/500000 (Pamir and Erentöz, 1975).

Maximum height was used as stand growth measured since it is not affected by silvicultural processes a lot, reflects growth progress best, is closely related with total efficiency on unit area and is easy to measure. Since maximum height level of the trees are reached at the age of 65 in the sample areas; and for identifying the effects of the factors other than age on maximum height, maximum height of the trees at 65 were analyzed statistically. In order to make a statistical analysis, information about exposure of the sample areas were converted into expressions in sinus and cosinus values (Carmean, 1965). Mutual relationships between maximum height valves and physiographic habitat factors, variables of soil, forest floor and needles were investigated by simple correlation analysis. Thus, variables which are of considerable effect on efficiency were determined. Stepwise regression analysis was made in order to identify the most coherent variables set models which are among the ones closely related with maximum height. As a result of these analyses, models which best explain height growth, were determined.

3. Results

3.1. Characteristics of research habitat

Türkmen Mountain is a massif lying between Eskişehir and Kütahya, between 39°16´-39°38´ northern latitudes and 30°06´-30°36´ eastern longitudes in northwest-southeast direction. The peak of the massif is Türkmen summit with an altitude of 1826 m. It was found that dacite and dacidictuff in northern exposure and riolite and riodacite main rocks in southern exposure are widespread. Apart from these main rocks, basalt, claystone, limestone are also seen. The massif predominantly survives from Neogene age; however, there are also working circles from Mesozoic, Jurassic-Cretaceous and Permian-Mesozoic ages (Pamir and Erentöz 1975).

Tree layer consists of Yellow pine in the research area. However, occasional existence of *Pinus nigra* ssp. *pallasiana* (Anatolian black pine), *Populus tremula* (Aspen) and individual existence of *Fagus orientalis* (Oriental, Common beech) have also been identified. The most widespread species in the scrub layer are *Cistus laurifolius* (Laurel-leaved cistus), *Quercus infectoria* (Tinctory oak), *Quercus pubescens* (Downy oak), *Quercus cerris* var. *cerris*

(Turkey oak), *Quercus trojana* (Macedonia oak), *Quercus robur* ssp. *robur* (Common oak), *Juniperus oxycedrus* ssp. *oxycedrus* (Prickly Juniper), *Juniperus foetidissima* (Smelling juniper), *Juniperus exelsa* (Grecian juniper), *Sorbus torminalis* var. *torminalis* (Wild service tree), *Rosa canina* (Dog rose), *Fagus orientalis* (Common beech, Oriental beech), *Pyracantha coccinea* (Firethorn) and *Crataegus pentagyna* (Hawthorn).

In north, while *P. sylvestris* ssp. *hamata* does not exist until 1200 m, it grows together with species belonging to genuses *P. nigra* ssp. *pallasiana, Q. infectoria, F. orientalis*, *P. tremula*, *Carpinus betulus* (Hornbeam), *Rosa canina* and *Rubus canescens* (Raspberry) in 1200-1300m; *P. nigra, F. orientalis, P. tremula, Q. infectoria, C. betulus, R. canina* and *R. canescens* between 1300-1400 m; *C. betulus*, *P. nigra*, *P. tremula*, *R. canina* and *R. canescens* in 1400-1500m; *P. tremula*, *R. canina* and *R. canescens* in 1500-1600m; *R. canina* and *R. canescens* in 1600-1700m; and *Crataegus*, *Thymus*, *Verbascum*, *Astragalus*, *Acanthalimon*, *Ballota* and *Onopordum* above 1700 m (Figure 2). *Quercus* and *Juniperus* constitute the main stand between 800-900 m elevations, while *P. nigra* ssp. *pallasiana* grows between 900-1200m, and *P. sylvestris* ssp. *hamata* between 1200-1700 m.

In south, while *P. sylvestris* ssp. *hamata* does not exist until 1400 m, it grows together with species belonging to genuses *P. nigra*, *C. laurfolius*, *Q. cerris, Q. pubencens*, *Q. infectoria*, *J. oxycedrus* and *R. canina* in 1400-1500 m; *P. sylvestris*, *P. nigra*, *P. tremula*, *C. laurifolius*, *Q. infectoria*, *Q. pubescens*, *Q. cerris*, *J. oxcedrus* and *R. canina* in 1500-1600 m; *P. sylvestris*, *P. nigra*, *C. laurifolius* and *J. oxycedrus* in 1600-1700 m and *Crataegus*, *Thymus*, *Verbascum*, *Astragalus*, *Acanthalimon*, *Ballota* and *Onopordum* above 1700 m. Concerning the southern exposure, *Quercus* and *Juniperus* constitutes the main stand up to 1100 m, *P. nigra* between 1100-1400 m and *P. sylvestris* ssp. *hamata* above 1400 m. It is clear that, Yellow pine spreads out between 1200-1700 m on the northern part and between 1400-1700 m on the southern part of the massif.

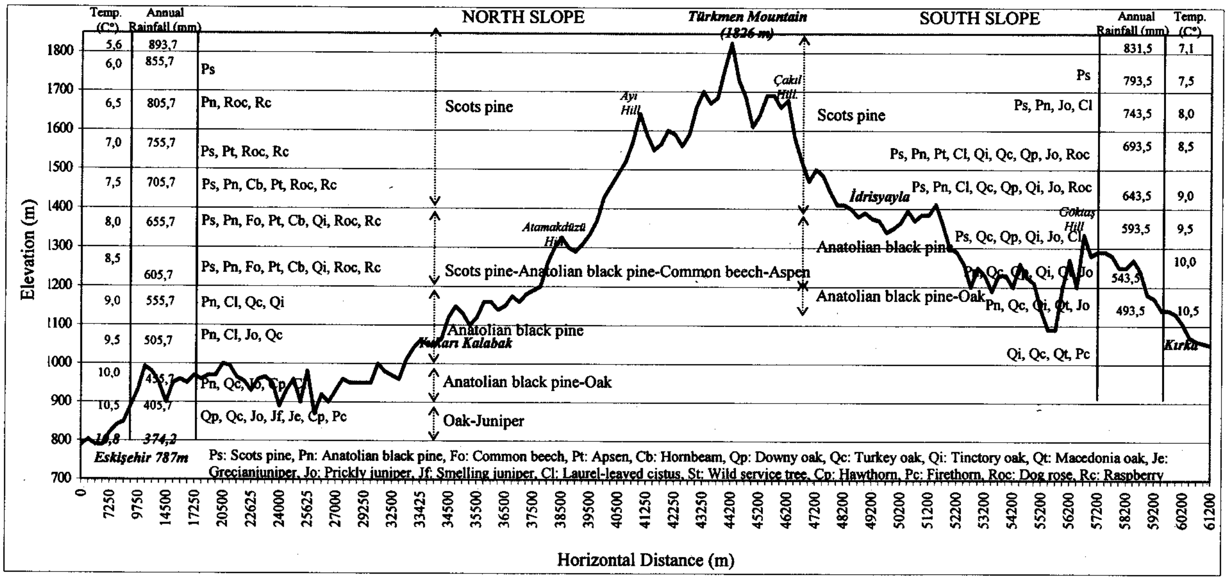

Figure. 3. Distribution of tree and shrub species on Eskişehir-Yukarı Kalabak-Türkmen Dağı-İdrisyayla-Kırka cross section

3.2. Findings belonging to physiographic factors, climate, soil, forest floor and needle characteristics

Annual average temperature and rainfall of the research area varies between 6.5-9.0 °C and 605.7-805.7 mm respectively. Although a moderate water deficit occurs at all elevations of north exposure in summer, water deficiency includes 4 months period (July-October) at 1250 m, 3 months period (July-September) at 1350-1550 m elevations, and 2 months period (August-September) at 1650 m elevation. Likewise, there is a moderate water deficit at all elevations of south exposure between July and September in summer (Table 2).

Soils of the research area were identified as podsolic grey-brown forest soils. Ah, Ael, Bst, BC and Cv horizons which are the common horizons in all profiles, exists in the soil profiles in the study area. Thickness of horizon in altitude steps was determined as 2.7-3.7 cm in Ah horizon, 7.8-12.2 cm in Ael horizon, 10.5-16.7 cm in Bst horizon, 17.7-24.5 cm in BC horizon and 40.2-55.7 cm in Cv horizon in average (Table 3). A meaningful statistical relationship between altitude and thickness of soil horizons (Ah, Bst, BC and Cv) was not found, while a ($P<0.05$) positive relationship was determined in Ael horizon.

Table 2. Mean values ($\overline{X}$) and standard deviations (s) belonging to site index, physiographic factors of sampling plots and some climatic parameters

Site index (m)	Elevation (m)	Slope (%)	Temperature (C°)	Rainfall (mm)
$\overline{X}$ (s)	$\overline{X}$ (s)	$\overline{X}$ (s)	$\overline{X}$ (s)	$\overline{X}$ (s)
14.86 (3.0)	1501 (137)	20.2 (9.3)	7.8 (0.7)	703 (62)

The type of forest floor on Türkmen Mountain was determined as moder and it was found that fermentation layer had the maximum weight in all altitude steps, followed by litter and humus layers. The weight of forest floor was determined as 677-1293 g/m^2 in litter layer, 1039-1996 g/m^2 in fermentation layer and 362-625 g/m^2 in humus layer in average (Table 4). In the correlation analysis made between altitude and forest floor layer weights, while a meaningful relationship was not found at litter and humus layers, a ($P<0.01$) positive relationship was found between fermentation layer. In booth northern and southern exposure areas, quantity of forest floor in unit area increases in a parallel way with the altitude. Between the quantity of forest floor and altitude in 1 m^2 area, a ($P<0.01$) positive relationship was found.

Fresh needle (n=1000 pieces) weight was determined as 29.82-41.79 g for one year-old needles, 34.48- 43.41 g for two year-old needles and 31.23-38.81 g for three year-old needles. A meaningful statistical relationship was not found between elevation and fresh needle weight. Dry needle weight was determined as 13.70-19.58 g for one year-old needles, 17.09-21.51 for two year-old needles, 16.48-20.37 for three year-old needles and a meaningful relationship was not found for two and three year-old needles while a ($P<0.05$) positive relationship was found for one year-old between weight and elevation (Table 5). Needle length was determined as 29.82-41.79 cm for one year-old needles, 34.48-43.41cm for two year-old needles, 31.23-38.81 cm for three year-olds and a meaningful relationship was not found between needle length and elevation.

Table 3. Mean ($\overline{X}$) and standard deviation (s) of variables in soil horizons

Variables	Ah	Ael	Bst	BC	Cv
	$\overline{X}$ (s)	$\overline{X}$ (s)	$\overline{X}$ (s)	$\overline{X}$ (s)	$\overline{X}$ (s)
Thickness of horizon (cm)	3.2 (0.8)	9.8 (2.5)	14.2 (4.9)	21.0 (6.2)	49.5 (11.9)
Fine soil (%)	54.1 (14.6)	57.0 (10.4)	61.0 (10.0)	61.5 (10.2)	53.5 (13.4)
Stoniness (%)	45.8 (14.6)	43 (10.4)	38.9 (10.0)	38.4 (10.2)	46.4 (13.4)
Sand (%)	68.8 (8.7)	61.7 (8.8)	58.9 (8.4)	61.0 (8.4)	60.0 (9.9)
Silt (%)	15.0 (4.9)	18.3 (4.6)	19.0 (4.5)	17.6 (4.8)	17.1 (4.4)
Clay (%)	16.1 (4.1)	19.8 (4.9)	21.9 (5.4)	21.2 (5.1)	22.8 (8.7)
Field capacity (%)	30.7 (6.6)	26.0 (4.6)	23.8 (4.4)	22.0 (4.3)	24.6 (8.0)
Permanent milting point (%)	14.8 (3.5)	10.8 (2.2)	12.2 (3.1)	11.7 (3.1)	11.2 (6.5)
Available water (%)	15.9 (4.3)	15.2 (3.2)	11.5 (2.4)	10.3 (2.3)	13.4 (2.9)
pH ½,5 H_2O	5.8 (0.2)	5.8 (0.2)	6.0 (0.2)	6.0 (0.3)	6.1 (0.3)
Electrical conductivity (mS/cm)	0.36 (0.08)	0.32 (0.06)	0.22 (0.06)	0.18 (0.04)	0.20 (0.04)
Organic carbon (%)	4.44 (1.44)	1.97 (0.75)	0.89 (0.48)	0.39 (0.23)	0.25 (0.22)
N (%)	0.19 (0.05)	0.11 (0.03)	0.08 (0.02)	0.06 (0.01)	0.04 (0.01)
P (ppm)	22.1 (22.7)	16.6 (19.7)	11.5 (15.3)	8.7 (13.1)	7.2 (12.3)
CEC (me/100 g)	23.0 (6.4)	16.1 (4.3)	13.4 (6.1)	11.6 (5.6)	14.0 (10.8)
Ca^{2+} (ppm)	2300 (806)	1602 (648)	1348 (879)	1218 (865)	1560 (1602)
Mg^{2+} (ppm)	222 (63)	190 (80)	189 (158)	185 (141)	208 (164)
K^+ (ppm)	305 (167)	253 (208)	250 (261)	252 (260)	279 (318)
Na^+ (ppm)	20.6 (10.8)	21.7 (15.1)	23.5 (17.9)	25.6 (23.1)	35.4 (47.6)
Fe^{2+} (ppm)	2.1 (1.4)	1.2 (0.9)	1.6 (1.0)	1.6 (1.3)	1.4 (1.0)
Cu^{2+} (ppm)	0.27 (0.14)	0.42 (0.19)	0.55 (0.27)	0.53 (0.24)	0.41 (0.19)
Zn^{2+} (ppm)	6.9 (2.9)	2.8 (1.8)	0.9 (0.6)	0.5 (0.2)	0.6 (0.4)
Mn^{2+} (ppm)	70.7 (41.5)	47.3 (29.1)	3.9 (5.1)	1.7 (2.0)	13.9 (19.8)
S (ppm)	18.8 (9.4)	10.9 (3.9)	6.1 (2.2)	4.4 (2.0)	4.1 (2.0)
B (ppm)	0.59 (0.41)	0.33 (0.23)	0.2 (0.2)	0.1 (0.1)	0.09 (0.11)

Table 4. Means ($\overline{X}$) and standard deviations (s) of variables belong to forest floor layers

Variables	Litter	Fermentation	Humus
	$\overline{X}$ (s)	$\overline{X}$ (s)	$\overline{X}$ (s)
Weight (g/m^2)	931 (309)	1483 (646)	524 (269)
N (%)	0.73 (0.11)	1.02 (0.08)	1.14 (0.07)
K (%)	0.15 (0.03)	0.19 (0.02)	0.24 (0.02)
Ca (%)	1.13 (0.13)	1.23 (0.17)	1.11 (0.19)
P (ppm)	621 (128)	1032 (146)	1288 (286)
Na (ppm)	78 (14)	121 (21)	164 (34)
Mg (ppm)	922 (75)	1212 (69)	1365 (86)
Fe (ppm)	687 (208)	3539 (832)	6281 (1205)
Cu (ppm)	4.8 (1.1)	10.1 (1.3)	12.1 (1.4)
Zn (ppm)	65 (9)	94 (11)	114 (13)
Mn (ppm)	558 (150)	1072 (342)	1713 (566)
S (ppm)	1525 (269)	1822 (297)	2207 (281)
B (ppm)	23.8 (6.5)	28.8 (5.8)	33.1 (5.2)

Table 5. Means ($\overline{X}$) and standard deviations (s) of variables belong to needles

Variables	One year old	Two years old	Three years old
	$\overline{X}$ (s)	$\overline{X}$ (s)	$\overline{X}$ (s)
1000 needle fresh weight (g)	37.55 (7.27)	38.63 (8.04)	35.82 (8.19)
1000 needle dry weight (g)	17.48 (3.35)	19.21 (3.98)	18.63 (4.24)
Needle length (cm)	4.8 (0.5)	4.8 (0.5)	4.3 (0.5)
Organic matter (%)	97.28 (0.33)	96.48 (0.46)	96.45 (0.63)
N (%)	1.09 (0.13)	1.04 (0.15)	0.92 (0.12)
P (ppm)	1307 (268)	1242 (254)	1026 (212)
K (%)	0.62 (0.12)	0.55 (0.11)	0.43 (0.06)
Na (ppm)	52.8 (14.5)	77.8 (26.9)	105.2 (42.82)
Ca (%)	0.20 (0.06)	0.40 (0.14)	0.46 (0.18)
Mg (%)	0.12 (0.01)	0.12 (0.02)	0.12 (0.02)
Fe (ppm)	99.4 (34.6)	199.1 (38.8)	218.1 (63.6)
Cu (ppm)	2.3 (1.0)	1.6 (0.9)	1.1 (0.8)
Zn (ppm)	51.2 (9.3)	62.8 (11.4)	67.1 (13.2)
Mn (ppm)	254 (98)	504 (190)	570 (220)
S (ppm)	1450 (277)	1784 (331)	1656 (279)
B (ppm)	28.5 (7.2)	31.5 (7.1)	34.5 (7.5)

3.3 Relations between site index and variables of physiographic factors, climate, soil, forest floor and needles

Relationships between site index and variables of physiographic factors, climate, soil, forest floor and needles were evaluated via correlation analysis.

Correlation analysis pointed at an important ($P<0.05$) positive statistical relationship between site index elevation and slope (Table 6). A positive correlation ($P<0.05$) was found between site index and precipitation, while annual mean temperature was non-significant (Table 6).

Table 6. Relations between site index and physiographic factors and climate

Variables	Elevation (m)	Slope (%)	Sinus slope	Cosinus slope	Slope position	Rainfall (mm)	Temperature (Cº)
Site index (m)	0.319*	0.310*	0,079^{ns}	0,074^{ns}	-0,085^{ns}	0.289*	-0.176^{ns}
ns: non-significant, *: significant at 0.05 level							

When the whole massif was evaluated as a whole regardless of exposure, a positive statistical relationship between site index elevation ($y=-4E–05x^2+0.1181x–76.31$; $P<0.05$) was evident. Site index increases until 1600 m and then decreases. A ($y=-6E-05x^2+0.1837x-122.34$; $P<0.05$) positive meaningful statistical relationship between site index and elevation was determined in northern exposure. Relationship between site index and elevation ($y=-9E–05x^2+0.2827x-214$; $P>0.05$) was found insignificant in southern exposure.

A meaningful ($P>0.05$) statistical relationship wasn't determined between site index and main rock. According to correlation analysis, results made between site index and percentage (In 100 g dry matter) values of soil horizons variables (Table 7); A ($P<0.01$) positive relationship between site index and fine soil in Ah horizon; a ($P<0.01$) negative correlation between site index and stoniness and a ($P<0.05$) positive correlation between organic carbon and total nitrogen were determined. In Ael horizon, a positive relationship between site index and horizon thickness, organic carbon available phosphorus ($P<0.05$) and total nitrogen ($P<0.01$) were determined; a ($P<0.05$) negative relationship between site index and dust was determined. In Bst horizon, a ($P<0.05$) positive relationship between site index and fine soil, a ($P<0.05$) negative one between site index and stoniness and humidity, and a ($P<0.01$) negative one between site index and dust were determined. In Cv horizon, a ($P<0.01$) positive relationship between site index and fine soil, a ($P<0.01$) negative relationship between site index and stoniness were found.

According to correlation analysis, results made between site index reserve values of soil horizons in 1 liter (Table 8): In Ah horizon; a ($P<0.01$) positive relationship between site index and fine soil, sand, organic carbon, N,

Table 7. Relations between percentage values of variables belong to soil horizons and site index

Variables	Ah	Ael	Bst	BC	Cv
Horizon thickness (cm)	0.006^{ns}	0.339*	0,265^{ns}	0,056^{ns}	0,057^{ns}
Fine soil (%)	0.387**	0,178^{ns}	0,346*	0,502**	0,512**
Stoniness (%)	-0.387**	-0,178^{ns}	-0,346*	-0,502**	-0,512**
Sand (%)	0,062^{ns}	0,265^{ns}	0,259^{ns}	0,191^{ns}	0,065^{ns}
Silt (%)	-0,045^{ns}	-0.311*	-0.393**	-0.306*	-0,282^{ns}
Clay (%)	-0,077^{ns}	-0,179^{ns}	-0,071^{ns}	-0,024^{ns}	0,068^{ns}
Field capacity (%)	0,066^{ns}	-0,149^{ns}	-0,243^{ns}	-0,076^{ns}	-0,021^{ns}
Permanent milting point (%)	0,129^{ns}	-0,076^{ns}	-0,070^{ns}	0,017^{ns}	0,035^{ns}
Available water (%)	-0,002^{ns}	-0,156^{ns}	-0.354*	-0,164^{ns}	-0,137^{ns}
pH ½,5 H_2O	-0,105^{ns}	-0,145^{ns}	0,023^{ns}	-0,141^{ns}	-0,134^{ns}
Electrical conductivity (mS/cm)	-0,034^{ns}	0,015^{ns}	-0,180^{ns}	-0,175^{ns}	-0,258^{ns}
Organic carbon (%)	0.318*	0.336*	-0,166^{ns}	-0,087^{ns}	0,023^{ns}
N (%)	0.318*	0.385**	0,181^{ns}	0,074^{ns}	0,211^{ns}
P (ppm)	0,278^{ns}	0.295*	0,224^{ns}	0,245^{ns}	0,214^{ns}
CEC (me/100 g)	0,267^{ns}	0,222^{ns}	-0,002^{ns}	0,098^{ns}	0,062^{ns}
Ca^{2+} (ppm)	0,252^{ns}	0,108^{ns}	0,001^{ns}	0,093^{ns}	0,072^{ns}
Mg^{2+} (ppm)	0,180^{ns}	-0,025^{ns}	-0,034^{ns}	0,062^{ns}	0,107^{ns}
K^+ (ppm)	-0,043^{ns}	-0,084^{ns}	-0,133^{ns}	-0,106^{ns}	-0,074^{ns}
Na^+ (ppm)	0,118^{ns}	-0,091^{ns}	-0,075^{ns}	-0,080^{ns}	-0,034^{ns}
Fe^{2+} (ppm)	-0,148^{ns}	-0,160^{ns}	-0,197^{ns}	-0,066^{ns}	0,018^{ns}
Cu^{2+} (ppm)	-0,091^{ns}	-0,242^{ns}	-0,241^{ns}	-0,095^{ns}	-0,105^{ns}
Zn^{2+} (ppm)	0,175^{ns}	0,261^{ns}	-0,165^{ns}	0,020^{ns}	-0,078^{ns}
Mn^{2+} (ppm)	0,001^{ns}	0,135^{ns}	-0,091^{ns}	0,004^{ns}	0,046^{ns}
S (ppm)	0,054^{ns}	0,124^{ns}	-0,030^{ns}	0,142^{ns}	0,092^{ns}
B (ppm)	0,222^{ns}	0,069^{ns}	0,058^{ns}	0,140^{ns}	0,273^{ns}
ns: non-significant, *: significant at 0.05 level, **: significant at 0.01 level					

CEC, Ca^{2+} and Mg^{2+}, a (P<0.05) positive relationship between site index and available water, P and Zn^{2+} and a (P<0.05) negative relationship between site index and stoniness were determined. It was determined that organic carbon and N (P<0.01), fine soil, sand, CEC, P, Zn^{2+} and S (P<0.05) contents in Ael horizons, were correlated with site index positively. In Bst horizon, there are a (P<0.01) positive relationship between site index and sand (P<0.01), fine soil and N (P<0.05), and a negative one (P<0.05) with stoniness. In BC horizon a (P<0.01) positive relationship between site index and fine soil, a (P<0.01) negative one between site index and stoniness and a (P<0.05) positive one between site index and clay, N and S were determined. In Cv horizon a (P<0.01) positive relationship between site index and available water, fine soil, sand, N and B, a (P<0.01) negative one between site index and stoniness and a (P<0.05) positive one between site index and clay and Mg^{2+} were determined.

According to correlation analysis, results made between site index values and reserve values (values which soil profiles include as pedons in 1 m^2 soil which is 1 m deep) (Table 9); positive relationship between site index and available water, fine soil, sand, clay, organic carbon, N on S amounts, positive relationship between site index and absolute soil depth, CEC and B amounts a (P<0.05) were determined.

When it comes to relationship between site index and litter, fermentation and humus layers of the forest floor (Table 10), a negative relationship between site index and B in the litter and humus layers (P<0.05) and positive relationship between N and total phosphorus in litter layer were determined (P<0.05). A meaningful statistical relationship between site index and reserve values of forest floor in 1 m^2 area was not found.

Concerning one year-old needles and site index; fresh needle weight and Mg (P<0.01), needle length and Zn were correlated with site index positively (P<0.05), while B is negatively (P<0.01) (Table 11). About two year-old needles; there is a positive relationship between site index and Mg and Zn (P<0.01) and there is a negative one between

Table 8. Relations between values of one litre soil variables belong to soil horizons and site index

Variables	Ah	Ael	Bst	BC	Cv
Available water (g/litre)	0,295*	0,152 ns	-0,065 ns	0,240 ns	0,462**
Fine soil (g/litre)	0,400**	0,329*	0,347*	0,568**	0,544**
Stoniness (g/litre)	-0,341*	-0,064 ns	-0,289*	-0,459**	-0,426**
Sand (g/litre)	0,369**	0,335*	0,369**	0,497**	0,451**
Silt (g/litre)	0,253ns	-0,041 ns	-0,148 ns	0,026 ns	0,210 ns
Clay (g/litre)	0,242 ns	0,070 ns	0,154 ns	0,313*	0,366*
Organic carbon (g/litre)	0,511**	0,532**	-0,057 ns	0,057 ns	0,178 ns
N (g/litre)	0,536**	0,556**	0,344*	0,355*	0,551**
P (mg/litre)	0,343*	0,346*	0,209 ns	0,281 ns	0,242 ns
CEC (me/litre)	0,464**	0,345*	0,131 ns	0,244 ns	0,261 ns
Ca^{2+} (mg/litre)	0,427**	0,216 ns	0,099 ns	0,196 ns	0,225 ns
Mg^{2+} (mg/litre)	0,410**	0,083 ns	0,045 ns	0,165 ns	0,291*
K^{+} (mg/litre)	0,117 ns	-0,040 ns	-0,099 ns	-0,053 ns	0,081 ns
Na^{+} (mg/litre)	0,256 ns	-0,017 ns	-0,019 ns	-0,024 ns	0,068 ns
Fe^{2+} (mg/litre)	0,020 ns	-0,072 ns	-0,073 ns	0,047 ns	0,185 ns
Cu^{2+} (mg/litre)	0,042 ns	-0,116 ns	-0,137 ns	0,080 ns	0,071 ns
Zn^{2+} (mg/litre)	0,365*	0,364*	0,089 ns	0,210 ns	0,056 ns
Mn^{2+} (mg/litre)	0,156 ns	0,215 ns	-0,003 ns	0,107 ns	0,133 ns
S (mg/litre)	0,260 ns	0,293*	0,160 ns	0,302*	0,251 ns
B (mg/litre)	0,357 ns	0,149 ns	0,093 ns	0,183 ns	0,399**

ns: non-significant, *: significant at 0.05 level, **: significant at 0.01 level

site index and B (P<0.01). For three year-old needles and site index; positive relationship between site index and needle length (P<0.05), Mg and Zn, positive relationship between site index and P (P<0.01) and finally a negative relationship between site index and B were determined (P<0.01).

3.4. Results of the stepwise regression analysis made between site index and variables of physiographic factors, soil and forest floor

To calculate the site index, stepwise regression and to determine the factors related with habitat which are effective on height growth and knowledge of variables combination, necessary analysis was made.

Table 9. Relations between values of soil in 1m³ volumes and site index

Variables	Site index	Variables	Site index
Available water (mm/m³)	0,490**	Ca^{2+} (g/m³)	0,243 ^{ns}
Solum (cm)	0,298*	Mg^{2+} (g/m³)	0,239 ^{ns}
Fine soil (kg/m³)	0,551**	K^{+} (g/m³)	0,019 ^{ns}
Stoniness (kg/m³)	-0,273 ^{ns}	Na^{+} (g/m³)	0,041 ^{ns}
Sand (kg/m³)	0,489**	Fe^{2+} (mg/m³)	0,133 ^{ns}
Silt (kg/m³)	0,215 ^{ns}	Cu^{2+} (mg/m³)	0,040 ^{ns}
Clay (kg/m³)	0,387**	Zn^{2+} (mg/m³)	0,269 ^{ns}
Organic carbon (g/m³)	0,442**	Mn^{2+} (g/m³)	0,178 ^{ns}
N (g/m³)	0,587**	S (g/m³)	0,395**
P (g/m³)	0,278 ^{ns}	B (mg/m³)	0,293*
CEC (me/m³)	0,299*		
ns: non-significant, *: significant at 0.05 level, **: significant at 0.01 level			

Table 10. Relations between percentage values of variables belong to forest floor layers and site index

Variables	Litter	Fermentation	Humus
Weight (g/m^2)	-0,040^{ns}	0,026^{ns}	0,034^{ns}
N (%)	0.300*	0,041^{ns}	-0,034^{ns}
P (ppm)	0.339*	-0,031^{ns}	-0,090^{ns}
K (%)	0,063^{ns}	0,075^{ns}	-0,021^{ns}
Na (ppm)	0,025^{ns}	0,215^{ns}	0,100^{ns}
Ca (%)	0,095^{ns}	-0,007^{ns}	0,028^{ns}
Mg (%)	0,083^{ns}	0,224^{ns}	0,004^{ns}
Fe (ppm)	0,090^{ns}	0,254^{ns}	0,141^{ns}
Cu (ppm)	0,266^{ns}	0,071^{ns}	-0,086^{ns}
Zn (ppm)	-0,099^{ns}	-0,003^{ns}	-0,212^{ns}
Mn (ppm)	-0,254^{ns}	-0,244^{ns}	-0,257^{ns}
S (ppm)	0,030^{ns}	0,093^{ns}	-0,019^{ns}
B (ppm)	-0.301*	-0,269^{ns}	-0.297*
ns: non-significant, *: significant at 0.05 level, **: significant at 0.01 level			

As a results of stepwise regression analysis made between percentage values of variables of physiographic factors related with site index, soil, needle and forest floor, it was determined that 38 variables have important relationship between site index. 5 models were proposed as a result of the stepwise regression analysis including all variables. The first model included one year-old needle length (X_1), [$SI=0.732+2.925(X_1)$, ($P<0.01$)] and percentage of the model's explanation to total change in the length was 27%. The second model included Zn value of one year-old needle (X_1) and three year old one (X_2), [$SI=-7.004+3.208(X_1)+0.0948(X_2)$, ($P<0.01$)] and percentage of the models' explanation to total change in the length was 44.1%. In the third model, one year-old needle length (X_1), Zn in three year-old needles (X_2) and P in soil's Ael horizon (X_3) existed [$SI=-8.461+3.196(X_1) +0.105(X_2) +0.0518(X_3)$, ($P<0.01$)] and percentage of the model's explanation to total change in the length was 55.6%. In the fourth model, one year-old needle length (X_1), Zn in three year-old needles (X_2) and P in soil's Ael horizon (X_3) and B in three year-old needles (X_4) exist [$SI=-1.305+2.560(X_1) +0.109(X_2) +0.05806(X_3) -0.130(X_4)$, ($P<0.01$)] and percentage of the model's explanation to total change in the length is 64.7%. In the fifth model, one year-old needle length (X_1), Zn in three year-old needles (X_2) and P in soil's Ael horizon (X_3) and B in three year-old needles (X_4) and Ael horizon thickness (X_5) exist [$SI=-2.049+2.341(X_1)+0.105(X_2)+0.05583(X_3)-0.131(X_4)+0.220(X_5)$, ($P<0.01$)] and these variables explain the 68.1% of the total change in length.

Table 11. Relations between variables belong to needles and site index

Variables	One year old needle	Two years old needle	Three years old needle
1000 needle fresh weight (g)	0.285*	$0,095^{ns}$	$0,239^{ns}$
1000 needle dry weight (g)	$0,229^{ns}$	$0,046^{ns}$	$0,185^{ns}$
Needle length (cm)	0.519**	$0,174^{ns}$	0.285*
Organic matter (%)	$-0,260^{ns}$	$-0,131^{ns}$	$-0,031^{ns}$
N (%)	$0,186^{ns}$	$0,206^{ns}$	$0,284^{ns}$
P (ppm)	$0,200^{ns}$	$0,250^{ns}$	0.380**
K (%)	$-0,110^{ns}$	$-0,228^{ns}$	$-0,017^{ns}$
Na (ppm)	$-0,112^{ns}$	$0,125^{ns}$	$-0,031^{ns}$
Ca (%)	$0,199^{ns}$	$0,170^{ns}$	$0,034^{ns}$
Mg (%)	0.328*	0.401**	0.317*
Fe (ppm)	$0,220^{ns}$	$-0,013^{ns}$	$-0,062^{ns}$
Cu (ppm)	$0,062^{ns}$	$0,015^{ns}$	$-0,214^{ns}$
Zn (ppm)	0.412**	0.424**	0.349*
Mn (ppm)	$-0,129^{ns}$	$-0,147^{ns}$	$-0,234^{ns}$
S (ppm)	$0,098^{ns}$	$0,172^{ns}$	$0,120^{ns}$
B (ppm)	-0.373**	-0.371**	-0.402**
ns: non-significant, *: significant at 0.05 level, **: significant at 0.01 level			

The variable with the highest contribution to the model was Zn in three year-old needles, and length of one year old needle, P in Ael horizon, B in three year-old needles and thickness of Ael horizon followed it respectively.

Stepwise regression analysis was made separately for reserve values in percent, 1 liter and 1 m^3 for variables belonging to physiographic factors and soil related with site index.

As a result, stepwise regression analysis made between percentages values of variables of physiographic factors related with site index and soil horizons, 4 models were proposed. In the first model, only the amount of fine soil in Cv horizon (X_1) existed [SI=8.735+0.114(X_1), (P<0.01)] and percentage of the model's explanation to total change in the length was 26.3%. In the second model, the amount of fine soil in Cv horizon (X_1) and organic carbon content in Ael horizon (X_2) existed [SI=6.332+0.111(X_1)+0.754(X_2), (P<0.01)] and it explained 35.8% of the total change. In the third model, amount of fine soil in Cv horizon (X_1) and organic carbon content in Ael horizon (X_2) and amount of dust in Bst horizon (X_3) existed [SI=11.474+0.07475(X_1)+0.947(X_2)-0.204(X_3), (P<0.01)] and it explained 42.5% of the total change. In the fourth model, amount of fine soil in Cv horizon (X_1) and organic carbon content in Ael horizon (X_2) and dust quantity in Bst horizon (X_3) and slope (X_4) existed [SI=10.347+0.06543(X_1)+0.968(X_2)-0.201(X_3)+0.07387(X_4), (P<0.01)] and it explained 47.6% of the total change in height growth.

As a result, stepwise regression analysis made between physiographic factors related with site index and reserve values of soil horizons in 1 liter, two models were proposed. In the first model only fine soil in BC horizon (X_1) exists [SI=3.621+0.01588(X_1), (P<0.01)] and it explains 32.3% of the change in the length. In the second model, fine soil quantity in BC horizon (X_1) and organic carbon quantity in Ah horizon (X_2) exist [SI=2.244+0.01369(X_1)+0.08541(X_2), (P<0.01)] and it explains the 49.2% of the change.

As a result of stepwise regression analysis made between physiographic factors related with site index and reserved values of soil in 1 m^3, two models were proposed. In the first model, there was only N (X_1) [SI=9.485+0.01246(X_1), (P<0.01)] and it explained 34.4% of the change. In the second model which explained 41.8% of the total change, N (X1) and S (X2) values existed [SI=7.940+0.01114(X_1)+0.604(X_2), (P<0.01)].

Two models were proposed as a result of regression analysis made between variables of forest floor related with site index. In the first model, only value of P (X_1) in the litter layer existed [SI=9.918+0.007946(X_1), (P<0.05)] and it explained 11.5% of the total change in the height growth. The second model included values of P (X_1) and B (X_2) in the litter layer [SI=13.269+0.007452(X_1)-0.127(X_2), (P<0.01)] and it explained 19.1% of the total change.

Three models were proposed as a result of stepwise regression analysis made between variables of one year-old needles related with site index. In the first model, there was only one year-old needle length (X_1) [SI=0.732+2.925(X_1), (P<0.01)] and it explained 27.0% of the total change. In the second model, one year-old needle length (X_1) and Zn values in one year-old needles (X_2) existed [SI=-2.710+2.555(X_1)+0.102(X_2), (P<0.01)] and it explained 36.7% of the total change. In the third model, which explained 44.3% of the total change in the height growth, there were values of one year-old needle length (X_1), Zn (X_2) and B (X_3) values in one year old needles [SI=2.604+2.046(X_1)+0.113(X_2)-0.121(X_3), (P<0.01)].

As a result of stepwise regression analysis made between variables of two year old needles related with site index, two models were proposed. In the first model, only Zn value in two year-old needles (X_1) existed [SI=7.867+0.111(X_1) , (P<0.01)] and it explained 18% of the total change. In the second model, Zn (X_1) and B (X_2)

values in two year-old needles existed [SI=12.638+0.130(X_1)-0.188(X_2), (P<0.01)] and it explained 37.7% of the total change. Four models were proposed as a result of stepwise regression analysis made between variables of three year-old needles. The first model contained only value of B (X_1) in the three year-old needles [SI=20.386-0.160(X_1), (P<0.01)], second one contained B (X_1) and Zn (X_2) values in three year-old needles [SI=14.951-0.173(X_1)+0.08772(X_2), (P<0.01)], third one contained B (X_1), Zn (X_2) and P (X_3) values in three year-old needles [SI=10.361-0.160(X_1)+0.08171(X_2)+0.004424(X_3), (P<0.01)], and last one contained B (X_1), Zn (X_2), P (X_3) in three year-old needles and three year-old needle length (X_4) [SI=0.01685-0.125(X_1)+0.08943(X_2)+0.005325(X_3)+1.758(X_4), (P<0.01)]. All these models explained the variations in the height growth as 16.2%, 31.0%, 40.7% and 50.0%, respectively..

4. Conclusions

While a positive relationship was found between the site index values of the trees in sample areas and altitude and slope, which are physiographic site factors, no relationship with exposure and slope position (distance from the top edge of the hillside) was found.

While the findings of one group of studies about the subject were similar, contrasting results were obtained in another group of studies. Çepel et al. (1977), in a study on Yellow pine, found a positive relationship between height growth and distance from the top edge of the hillside, and a negative relationship with altitude; however they could not find a statistical relationship with slope. In another study on Yellow pine by Çepel and Dündar (1980), a positive relationship between site index and distance from the top edge of the hillside was found, while no meaningful relationship between site index and exposure was identified. In a study made in *Pinus radiata* plantations in Spain, a negative relationship between site index and altitude in Atlantic sites was found, while no meaningful relationship could be found in Mediterranean sites. Exposure is expected to have an effect on height growth owing to the fact that it is a factor considerably affecting heat and humidity climates in a place. In our study, however, the fact that exposure did not prove to be an effective factor on height growth can be explained by the difficulties of inserting exposure as a parameter in numerical values into statistical calculations as pointed out by Carmean (1965), and the fact that our study was not able to from local climate zones because it had a round outline. Slopes of the sample areas alternate between 3-40%, and a positive relationship was found between height growth and slope. Similar results were reached at the end of a study on Fir by Saraçoğlu (1989). The researcher notes that site index in fir changes with slope, and firs develop well in sites with a slope of 20-40%. Because water deficiency occurs in soil in the vegetation period, it is the minimum factor in our area of study. The increase in precipitation in proportion to altitude results decrease in the water deficiency, which, in turn, positively affects the growth of Yellow pine.

While a positive relationship was found between site index and rainfall, no relation with mean annual temperature was found. The increase in the rainfall of the site was of influence on the height growth of Yellow pine because there is a water deficiency in our area of study which is in the twilight area to steppes. Similarly, at the end of a study in Douglas-fir by Corona et al. (1998) a positive relationship was determined between height growth and annual rainfall.

No meaningful relationship in terms of statistics could be determined between site index and main rock. It is estimated that this situation stems from the fact that dacite and riolite main rocks are of the same origin.

Between the percentage values of the variables belonging to soil horizons and site index values: a positive relationship of site index with fine soil, organic carbon and total nitrogen; and a negative relationship with stoniness were established in the Ah horizon. A positive relationship of site index with horizon depth, organic carbon, available phosphor, and total amount of nitrogen, while a negative relationship with silt, were determined in the Ael horizon. A positive relationship of site index with fine soil, a negative relationship with stoniness, available humidity and with silt were found in the Bst horizon. A positive relationship of site index with fine soil, a negative relationship with stoniness and silt were found in the BC horizon. There is a positive relationship between site index and fine soil, and a negative relationship with stoniness. In relation to the increase in the eluviation horizon (Ael) thickness, height growth increased. The state is more in relation with the rainfall in the site. An increase in the rainfall caused a rise in the thickness of the Ael horizon, and the increase in the rainfall in the site, in turn, had a positive effect on the height growth of Yellow pine. The increase in the amount of fine soil and the fall in stoniness in the Ah, Bst, BC and Cv horizons positively affected the height growth of Yellow pine. However, the increase in the amount of silt in the Ael, Bst and BC horizons, in which tree roots were densely spread, had a negative effect on the height growth of Yellow pine. Silt affects air and water capacities of soil negatively by plugging in the pores. The percentage of available humidity in the Bst horizon gave a negative relationship with height growth. However, a positive relationship was found between site index and available water capacities in 1 liter and 1 m^3 volume of soil horizons. Therefore, this case proves that calculated reserved values should be used in evaluation instead of percentage values of available water out of which analysis results are obtained. Positive relationships were found between site index and total nitrogen and organic matter amounts in the Ah and Ael horizons, which are top soil horizons. The increase in the total amount of nitrogen and organic carbon in soil had a positive effect on the height growth of Yellow pine. A positive relationship was found between site index and the available phosphor amount in the Ael horizon. However, no statistical relationships were found between site index and the percentage values of micro nutritional elements belonging to the soil horizons.

According to values in 1 liter volume of soil horizons, a positive relationship between site index and fine soil, sand, organic carbon, N, CEC, Ca^{2+}, Mg^{2+}, available water, P, Zn^{2+}, and a negative relationship with stoniness were found in the Ah horizon. In the Ael horizon, there is a positive relationship of site index with organic carbon, N fine soil, sand, CEC, P, Zn^{2+} and S. In the Bst horizon, there exists a positive relationship of site index with sand, fine soil and N, but there is a negative relationship with stoniness. In the BC horizon, a positive relationship of site index with fine soil, clay, N and S; a negative relationship with stoniness were determined. In the Cv horizon, a positive relationship of site index with available water, fine soil, sand, N, B, clay and Mg^{2+} ; a negative relationship with stoniness were established. In the Ah and Cv horizons, a positive relationship was found between available water capacity and site index. Height growth increased in correlation with the rise in available water capacity. In all the horizons, positive relationships were found between site index and the amount of fine soil in 1 liter volume, while negative relationships were found between site index and the amount of stoniness in all horizons except the Ael horizon. The increase in the amount of fine soil and the decrease in stoniness in unit volume had a positive effect on height growth. Again, positive relationships were found between amount of sand and site index in all the soil horizons. There exist close relations between the amount of sand in soil and the height growth of Yellow pine. Site index also correlated positively to the amount of clay in 1 liter volume of the BC and Cv horizons. Close positive relationships between site index, the organic matter in the Ah and Ael horizons, and the total amount of nitrogen in all horizons were found. Similarly, available phosphor, CEC and available zinc in the Ah and Ael horizons had positive impact on height growth. Cation exchange capacity, which probably increases with organic matter in top soil horizons, affects the height growth of Yellow pine positively. A positive relation was found between site index and Ca^{++} and Mg^{++} in 1 liter volume of the Ah horizon. Sulphur in the Ael and BC horizons, and the amount of available boron in the Cv horizon showed a positive correlation with site index.

Positive correlations were determined between site index values and available water, fine soil, sand, clay, organic carbon, N, S, solum, CEC and B amounts in 1 m^3 volume of the soils. The available water capacity in 1 m^3 volume showed a strong correlation with site index. Height growth of Yellow pine showed an increase with the amount of water uptaken by the plant in 1 m^3 volume of soil. The increase in the solum had a positive impact on the height growth of Yellow pine. The increase in reserved values in1 liter volume and in per cent of the soil horizons and the increase in the amounts of fine soil, sand, clay, organic matter and total amount of nitrogen in 1 m^3 volume alike had a positive impact on height growth. Again, the cation exchange capacity of soil in 1 m^3 volume and the amounts of sulphur and available boron affected the height growth of Yellow pine positively.

Similar results were obtained out of the studies which investigate the relationships between soil characteristics and the height growth of forest trees. Among the percentage values of soil characteristics, nitrogen, amount of fine soil, and skeleton and soil reactions were established as factors determining the height growth in Yellow pine. As for reserved values, solum, nitrogen, amount of fine soil and available water capacity showed meaningful statistical correlations with site index (Çepel et al., 1977). In another research on Yellow pine, meaningful statistical relationships were found between site index and: nitrogen and amount of fine soil, which are of Z_1 zone (the A horizon) characteristics; soil reaction, nitrogen, phosphor and horizon thickness, which are of Z_2 zone (B and Cv) characteristics; and amount of fine soil, nitrogen, organic matter, available water capacity and potassium, which are of soil characteristics belonging to reserved values (Çepel and Dündar, 1980). A positive correlation of site index with soil depth, the soil type in the B horizon and the thickness of B horizon was found in a study on Oriental spruce (Daşdemir, 1992). In Calabrian pine, a strong relationship between site index and available water capacity in the A and AB horizons was found. AB horizon depth, pH value of top soil as well as nitrogen and phosphor reserves of soils also show up as factors of considerable importance for height growth (Zech and Çepel, 1972). In another study was made on Calabrian pine, a positive correlation of site index with pH, organic matter and total amount of nitrogen and Ca in the Ah horizon; a negative correlation with pH, organic matter, total amount of nitrogen and Mg in the A horizon; a negative correlation with silt + clay, amount of fine soil, silt, clay and CEC; a positive correlation with the pH in the B horizon; and a positive correlation with sand, Mg, K, organic matter and total amount of nitrogen in the Cv horizon were found. In Yellow pine, skeleton volume and amount of organic matter in the A_2 and Cv horizons; the amount of silt + clay in the B horizon and the amount of fine soil in the Cv horizon; and according to reserved values, skeleton volume of the A_2 horizon, the amount of clay and organic matter, and silt + clay amount of the Cv horizon appeared as factors having a collective effect on the height growth of Yellow pine.

A negative relationship was found between site index values and B content of litter and humus layers; while a positive relationship with N and P in the litter layer was found.

According to results of stepwise regression analysis between site index and the variables belonging to physiographic factors, climate characteristics, forest floor characteristics, the percentage values of soil horizons which are only in correlation to site index, the amount of fine soil in the Cv horizon, the amount of organic carbon in the Ael horizon, the amount of silt in the Bst horizon and slope entered the regression equation. In the equation, the four independent variables explained variation in site index at a rate of 47.6%. According to results of stepwise regression analysis between site index and the variables belonging to physiographic factors, climate characteristics, forest floor characteristics the reserved values in 1 liter volume of soil horizons which are only in correlation to site index, the amount of fine soil in the BC horizon and the amount of organic carbon in the Ah horizon entered the regression equation. In the equation, the two independent variables explained variation in site index at a rate of 49.2%. Finally, according to results of stepwise regression analysis between site index and the variables belonging to physiographic factors, climate characteristics, forest floor characteristics the reserved values in 1 m^3 volume of soils which are only in correlation to site index, N and S in 1 m^3 pedons entered the regression equation. In the equation, the two independent variables explained site index at a rate of 41.8%.

According to the stepwise regression analysis between site index and physiographic factors and the percentage values of soil horizons; elevation, slope position, nitrogen and bulk density of fine soil entered the regression equation, and the determination coefficient (R^2) of this equation was found as 0.32 in another study on Yellow pine in Turkey. According to the multiple regression analysis between site index and reserved values of soil characteristics; sand, silt, nitrogen, phosphor, available water capacity and horizon thickness entered the regression equation, and the degree of these six factors of determining the change in the site index (R^2) was found as 0.39 (Çepel et. al., 1977).

In a study which investigates the relationships between site factors and the height growth of Yellow pine in England, it was noted that the variations in growth all over England were correlated to solar radiation, soil texture and moisture content of soil, and that the three variables explain 69% of the change in growth (White, 1982).

In a study made in Italy, it was noted that the site index of the Douglas-fir plantations were correlated with exposure, annual water surplus, annual rainfall, clay in a depth of 25-50 cm of soil, and the total amount of lime, and that the five variables explained 58% of the change in height (Corona et. al., 1998).

Five variables were found to be correlated with site index according to results of correlation analysis between variables belonging to one year-old needles and site index. In the stepwise regression analysis between site index and these five variables, needle length, Zn and B entered the regression equation. In the equation, these three independent variables explained variation in site index at a rate of 44.3%. The correlation analysis between site index and the variables belonging to two year-old needles revealed three variables in relation with site index. In the stepwise regression analysis between these variables and site index, Zn and B entered the regression equation. In the equation, these two independent variables explained variation in site index at a rate of 37.7%. The correlation analysis between site index and the variables belonging to three year-old needles revealed five variables in relation with site index. In the stepwise regression analysis between these variables and site index, B, Zn, P and needle length entered the regression equation. In the equation, these four independent variables explained variation in site index at a rate of 50.0 %.

In a study on Yellow pine by Çepel and Dündar (1985); Zn, Cu, N, P and K entered the regression equation by the multiple regression analysis between site index and the nutritional elements in one year-old needles, and the determination coefficient R^2 of this equation was found as 0.39. In a study on Yellow pine by Dündar (1980), stepwise regression analysis between site index and the nutrients in one year-old needles, and the determination coefficient R^2 of the equation into which five variables entered, were determined as 0.53. These variables were B, Cu, P, Si and K.

When assessed together with physiographic site factors, climate characteristics and forest floor characteristics; percentage values belonging to soil horizons, 1 liter volume and 1 m^3 volume pedons explained the growth of Yellow pine at rates of 47.6%, 49.2%, 41.8%, respectively. When the closeness of the results and the easiness in application are considered, it is more convenient to use the percentage values of the variables belonging to soil horizons with physiographic site factors, climate characteristics, and forest floor characteristics. We reached the conclusion that the prospective site index of Yellow pine could be calculated on the Türkmen Mountain and in similar sites by using the equation below, which has a determination coefficient (R^2) of 47.6%. [H=10.347+0.06543 (Fine soil in the Cv horizon)+0.968 (Organic carbon in the Ael horizon)-0.021 (Silt in the Bst horizon)+0.07387(Slope)].

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