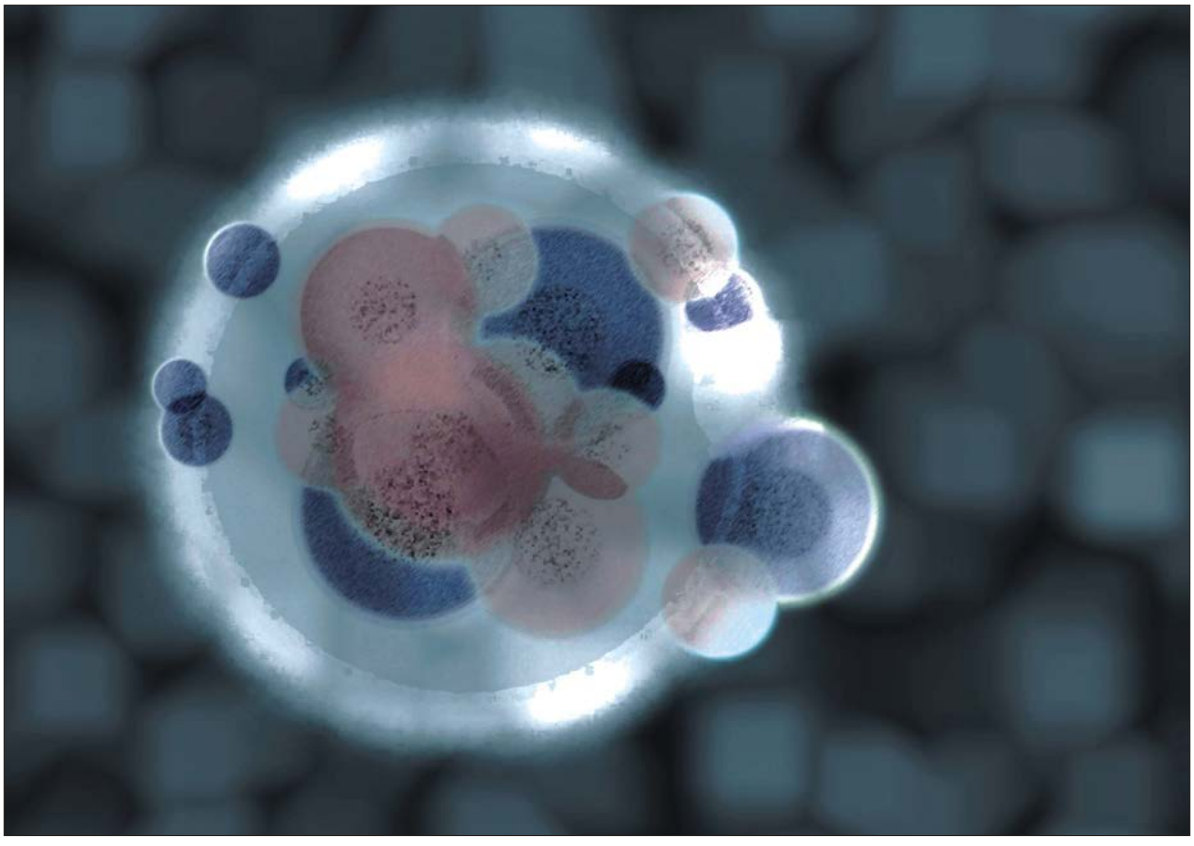

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Relationships Between Different Growth Parameters and Damage of Harmful Insects in Crimean Pine of Ilgaz Mountain, Cankiri, Turkey

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Abstract: In this study, five sample plots were selected from pure Crimean pine (*Pinus nigra* Arnold. subsp. *nigra* var. *caramanica* (Loudon) Rehder.) stands and DBH, height and crown diameter were measured on the live Crimean pine trees, of which DBH was higher than 4 cm, in these sample plots in Ilgaz Mountain, Cankiri, Turkey. At the end of the regression analysis carried out on the data of a total of 239 trees, it was determined that there were statistically significant ($p<0.001$) and strong ($R^2>0.50$) relationships between DBH, height and crown diameter variables in Crimean pines. The strongest relationship determined was the crown diameter-height relationship ($R^2 = 0.977$), followed by the height-DBH ($R^2 = 0.883$) and crown diameter-DBH ($R^2 = 0.851$) relationships, respectively. The results of the study indicated that the height-DBH and crown diameter-height relationships can be described by the second-degree polynomial model, while the crown diameter-DBH relationship can be described by the power model and heights and crown diameters can be estimated by means of DBH, of which measurement is easy, in Crimean pines of the research area. According to inspections on bark samples which obtained from Crimean pines in sample plots and catches at the light trap, *Ips acuminatus* (Gyll.), *Orthotomicus erosus* (Woll.), *Pityogenes quadridens* (Hartig) (Coleoptera: Scolytidae), *Dendrolimus pini* (L.) (Lepidoptera: Lasiocampidae) and *Sphinx pinastri* (L.) (Lepidoptera: Sphingidae) were determined at stands of 10-60 cm dbh, 50-110 age, 40-70% slope, generally south and southeast aspects and at elevation of 1280-1400 m where Crimean pine dominated.

Key words: Crown diameter, diameter at breast height, tree height, *Pinus nigra* Arnold. subsp. *Nigra* var. *caramanica* (Loudon) Rehder, regression analysis, harmful insects

INTRODUCTION

Turkey is between Asia and Europe continents and surrounded by seas at three sides and also has a rich biological diversity due to her climatic, soil and topographic structure. Ilgaz Mountain is one of the rare natural and essential to protect forests, both nationally and internationally, due to its interesting geographic-geomorphologic structure, richness in unique plant societies, insect species and diversity.

Crimean pine (*Pinus nigra* Arnold. subsp. *nigra* var. *caramanica* (Loudon) Rehder.)'s range extents to 2.527.685 ha as pure stands in Turkey. Distribution of this tree species covers Thrace, western part of Yesilirmak in Black Sea region (except the eastern part of Black Sea region), Aegean, Marmara, Central and Eastern Anatolia regions. Crimean pine is one of the main coniferous forest tree species in steppe region. It avoids sea facing slopes in its distribution area. Crimean pine exists as pure stands at elevations between 400-1400 m and as mixed stands with Scots pine at elevations between 1400-1700 m in Western and Central Black Sea regions. It also exists as stands beneath 900 m and as individual trees below 1400 m elevation (Genc, 2004).

Crimean pine in this study is the dominant tree species at the south aspect of Ilgaz Mountain at elevations between 1280-1400 m. Previous studies suggested that damage of bark beetles is highly related to certain properties (i.e., dbh, crown diameter, age, tree count per ha, elevation) of trees (Witrylak, 1995; Capecki, 1982; Struble and Johnson, 1955; Massey and Parker, 1981; Christiansen and Bakke, 1988; Tsankov, 1989; Martin and Cobos, 1986; Simsek, 2003; Simsek and Oner, 2003). Thus, DBH, tree height and crown diameter parameters have a great importance in regard to both in silvicultural practices and control of bark beetles. However, determination of parameters mentioned in lesser time and labor, needs certain modeling studies.

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There is a close relationship between tree parameters such as diameter, height, crown size and bole volume (Philip, 1994). Using these allometric relationships, a dimension of which measurement is difficult can be estimated by means of other dimensions which can easily be measured (Kalipsiz, 1984). As a matter of fact, using the height-DBH relationship, heights can be estimated by means of DBHs (Saracoglu, 1988; Caliskan, 1991).

In this study, the relationships between individual tree DBH, height and crown diameter were investigated in Crimean pine in the forests of Ilgaz Mountain, Cankiri, in 2000-2005. Thus, the possibilities of determination of height and crown diameter variables by means of regression equations for easier study and at less cost in the studies of ground-based forest inventory and stand structure determination to be made in the pure Crimean pine stands of the research area were evaluated.

MATERIALS AND METHODS

This study was carried out in order to determine the relationships among dbh, height and crown diameter of Crimean pine and damage of harmful insects in Crimean pine stands. The main materials of the study were Crimean pines and insects. Other material were tape, calipers, heightmeter (Blume-leis), increment borer, GPS, clinometer, Pennsylvania type light trap, stereo-microscope, thermal jug and 1/25000 scaled stand types map.

The data used in the study were obtained from the natural pure Crimean pine stands at elevations between 1280-1400 m of south aspects of Ilgaz Mountain that is located in the Ilgaz district of the Cankiri province. Transition climate zone from Central Anatolian steppe to Black Sea climate is seen at mid and upper elevations of the mountain. Five sample plots were selected from the pure Crimean pine stands, which had a normal structure, in the direction perpendicular to the contour lines. The sample plots were at 10×50 m dimensions. There were only Crimean pine in the sample plots 1, 2, 3 and 4 and 1 Uludag fir (*Abies nordmanniana* subsp. *bornmulleriana* Mattf.) and 2 Scots pines (*Pinus sylvestris* L.) in addition to Crimean pines in the sample plot 5. Some site characteristics of the sample plots are given in Table 1.

DBH, height and crown diameter of the live Crimean pine trees, of which DBH was higher than 4 cm, in the sample plots were measured; DBH, height and crown diameter were determined to the nearest 1 cm, 0.25 and 0.1 m, respectively. DBH was calculated as the mean of the two measurements that were made in the direction perpendicular to each other by a caliper, tree height was measured by a heightmeter. Crown diameter was calculated by measuring and adding the radii of the crown projection areas in four directions and then by dividing into 2 the value obtained. In addition, by taking the mean of the ages of the 3 dominant trees in the stand overstory, the mean ages of the sample plots were found to be 57, 72, 81, 93 and 109, respectively.

Table 1: Some site characteristics of the sample plots

Sample plot no.	Location	Elevation (m)	Aspect	Slope (°)	Relief
1	Kofunnu	1280	North	10	Middle slope
2	Dikencag	1300	Southeast	17	Middle slope
3	Mulayim	1350	Northeast	30	Middle slope
4	Ortaburun	1380	South	22	Upper slope
5	Arpadagi	1400	Southwest	10	Upper slope

The regression analysis was applied to determine whether there was a statistical relationship between DBH, height and crown diameter in Crimean pines (Kalipsiz, 1981). The data of a total of N = 239 trees measured in all sample plots were included in the analysis; thus, the relationships between individual tree height-DBH, crown diameter-DBH and crown diameter-height were tried to determine. The selection of the regression model was based on the coefficient of determination of the model (R^2) and the standard error of estimate ($S_{y.x}$) (Avery and Burkhart, 1994). The first item was accepted as the independent and the second item was accepted as the dependent variable in all types of relationships. A confidence level of p = 0.05 was used for statistical significance in all statistical analyses; and the analyses were carried out by using Minitab R13 package.

Bark samples obtained from Crimean pines at various ages and dbh and insects collected from light trap were brought to laboratory in thermal jug and investigated under stereo-microscope and then determined insects were identified. Soil samples which represent study area were brought to laboratory and both physically and chemically analyzed.

RESULTS

Tree height-DBH relationship: The regression analysis showed that a second-degree regression model established between these two variables and the model was statistically significant (F = 848.02; p<0.001). The regression equation was:

$$H = -6.6500 + 1.4300\ (DBH) - 0.0146\ (DBH)^2 \quad (1)$$

It was found that the coefficient of determination and the standard error of estimate were $R^2 = 0.883$ and $S_{H,\ DBH} = 2.035$, respectively. The regression coefficients (b_0, b_1) were also significant (p<0.001). Thus, it is seen that there is a strong positive, nonlinear relationship

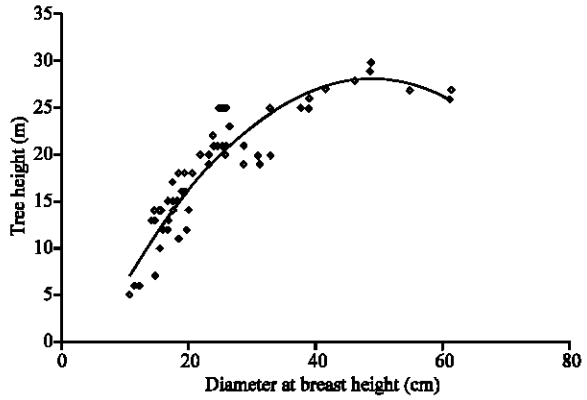

Fig. 1: The relationship between tree height and DBH

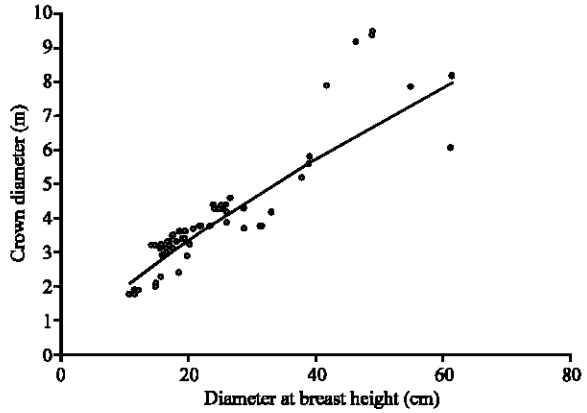

Fig. 2: The relationship between crown diameter and DBH

between tree height and DBH (Fig. 1). Because DBH explained 88.3% of the observed variation in tree height.

The crown diameter-DBH relationship: At the end of the regression analysis, it was determined that a power regression model established between these two variables and the model was statistically significant (F = 1286.86; p<0.001). The regression equation was:

$$CD = 0.3258\ (DBH)^{0.779} \quad (2)$$

It was found that the coefficient of determination and the standard error of estimate were $R^2 = 0.851$ and $S_{CD, DBH} = 0.1376$, respectively. The regression coefficients (b_0 and b_1) were also significant (p<0.001). Thus, it is seen that there is a strong positive, nonlinear relationship between crown diameter and DBH (Fig. 2). Because, DBH explained 85.1% of the observed variation in crown diameter.

The crown diameter-tree height relationship: The regression analysis indicated that a second-degree

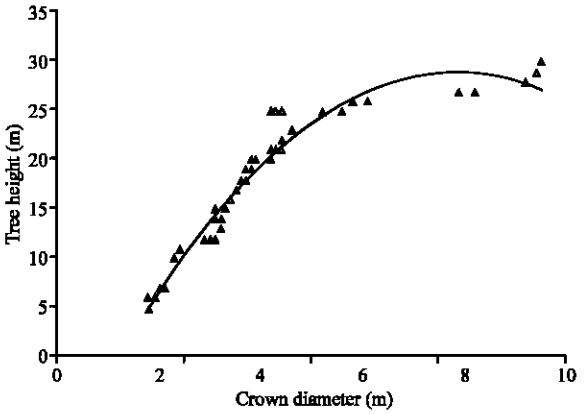

Fig. 3: The relationship between crown diameter and tree height

regression model established between these two variables and the model was statistically significant (F = 5134.62; p<0.001). The regression equation was:

$$H = -5.44 + 14.2\ (CD) + 1.44\ (CD)^2 \quad (3)$$

It was found that the coefficient of determination and the standard error of estimate were $R^2 = 0.977$ and $S_{H, CD} = 1.058$, respectively. The regression coefficients (b_0, b_1, b_2) were also significant (p<0.001). Thus, it is seen that there is a strong positive, nonlinear relationship between crown diameter and tree height (Fig. 3). Because, crown diameter explained 97.7% of the observed variation tree height.

Soil analysis: Soil texture of study area was dusty-clay (63%), 6.00-6.37 pH (slightly acidic), poor in lime (14%) and poor in organic matter (4.10-0.69%).

Harmful insects: According to inspections on bark samples which obtained from Crimean pines in sample plots and catches from the light trap, *Ips acuminatus* (Gyll.), *Orthotomicus erosus* (Woll.), *Pityogenes quadridens* (Hartig) (Coleoptera: Scolytidae), *Dendrolimus pini* (L.) (Lepidoptera: Lasiocampidae) and *Sphinx pinastri* (L.) (Lepidoptera: Sphingidae) were determined to be important pests at stands of 10-60 cm dbh, 50-110 age, 40-70% slope, generally south and southeast aspects and at elevation of 1280-1400 m where Crimean pine dominated (Simsek, 2002).

DISCUSSION

It was determined that the regression models established between DBH, height and crown diameter variables of Crimean pines in the research area were

statistically significant ($p<0.001$). That the R^2 value is more than 0.50 in the models established indicates that there are strong relationships between these three variables (Kalipsiz, 1981). The strongest relationship determined was the crown diameter-tree height relationship ($R^2 = 0.977$), followed by the tree height-DBH ($R^2 = 0.883$) and crown diameter-DBH ($R^2 = 0.851$) relationships, respectively.

The relationships between height and DBH were investigated in many studies (Akalp, 1983; Demirci and Gul, 1993; Zhang, 1997; Peng, 1999; Peng *et al*., 2001; Colbert *et al*., 2002). In these studies carried out on various tree species, it was determined that there was a strong relationship between height and DBH and this relationship was described by various nonlinear regression models. Kalipsiz (1984) stated that the relationship between height and DBH was in the shape of a parabola segment in even-aged and one-storied stands and could be described by a second-degree polynomial (parabola); this relationship was in the shape of S-curve in selection forests. In the present study, the height-DBH relationship was described by a second-degree polynomial model as suggested by Kalipsiz (1984).

There are many studies investigating the relationships between crown diameter and DBH (Akalp, 1983; Sun, 1977; Gering and May, 1995; Hasenauer, 1997; Bragg, 2001; Avsar, 2004). Francis (1988) and Foli *et al*. (2003) also investigated the crown radius-DBH and crown diameter-bole diameter (3.96 m above ground) relationships, respectively. In these studies carried out on various tree species, it was determined that there was a strong relationship between crown diameter and DBH (bole diameter) or crown radius and DBH and this relationship was generally described by the simple linear model, nonlinear models were also used in some studies. In the present study, the crown diameter-DBH relationship was described by the power model, a nonlinear model.

On the other hand, Hasenauer (1997) determined that the relationship between crown diameter and height was generally strong in various tree species and this relationship could be described by the simple linear model. In the present study, the crown diameter-height relationship was described by a second degree polynomial model as in the tree height-DBH relationship.

In this study, we determined that diameters of Crimean pines vary between 10-60 cm, ages between 50-110 and slopes vary between 40-70%. Thus, we reached the conclusion those areas where Crimean pines grow and specified conditions rule are appropriate for bark beetle breeding. Furthermore, determination of insects [*Ips acuminatus* (Gyll.), *Orthotomicus erosus* (Woll.), *Pityogenes quadridens* (Hartig) (Coleoptera: Scolytidae), *Dendrolimus pini* (L.) (Lepidoptera: Lasiocampidae) and *Sphinx pinastri* (L.) (Lepidoptera: Sphingidae)] support this conclusion.

Previous studies show that *D. pini* is an important harmful insect of pines in Turkey, Norway and Russia (Adolfsson, 1984; Grimal'skii and Entin, 1980; Malyi, 1978). Outbreaks of this insect are related to climatic conditions (Lesniak, 1976; Klimetzek, 1971) and its damage adversely affects the radial growth (Ierusalimov, 1977). *S. pinastri* is a main pest in The Netherlands (Meerman and Schouten, 1980). This moth may exist in pine forests until 1600 m elevation at Alps whereas it may exist until 200 m elevation in Lebanon (Pittaway, 1993). *S. pinastri* defoliated pines in Marmara Region in Turkey (Mol and Avci, 1997) and Simsek (2002) collected many samples during his studies in Ilgaz.

Results of other studies on this subject (Acatay, 1963; Besceli, 1969; Capecki, 1982; Chararas, 1975; Canakcioglu and Mol, 1998; Kaczmarek *et al*., 1992; Klein, 1984;Schimitschek, 1953; Sekendiz, 1987; Starzyk and Lusczak, 1982; Simsek, 2000, 2001, 2002, 2003; Simsek and Oner, 2002; Simsek and Ozdemir, 2000; Tiberi, 1997; Toper, 2000; Tsankov *et al*., 1994; Yuksel, 1997; Witrylak, 1995) are similar to support present findings.

From the results of present study, it was determined that heights and crown diameters could be estimated by means of DBH, of which measurement is easy, in the studies of ground-based forest inventory and stand structure determination to be made in the pure Crimean pine stands of the research area. The crown diameter-height relationship, which is stronger than the crown diameter-DBH relationship, should be used in the estimate of crown diameter. In addition, the height-DBH and crown diameter-height relationships can be described by the second-degree polynomial model ($Y = b_0 + b_1X + b_2X^2$), while the crown diameter-DBH relationship can be described by the power model ($Y = b_0X^{b1}$) in Crimean pines of the research area. In this study 3 bark beetles (*P. quadridens*, *I. acuminatus*, *O. erosus*) and 2 lepidopterous insects (*D. pini* and *S. pinastri*) have been determined to be the most important pests of Crimean pine in research area.

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