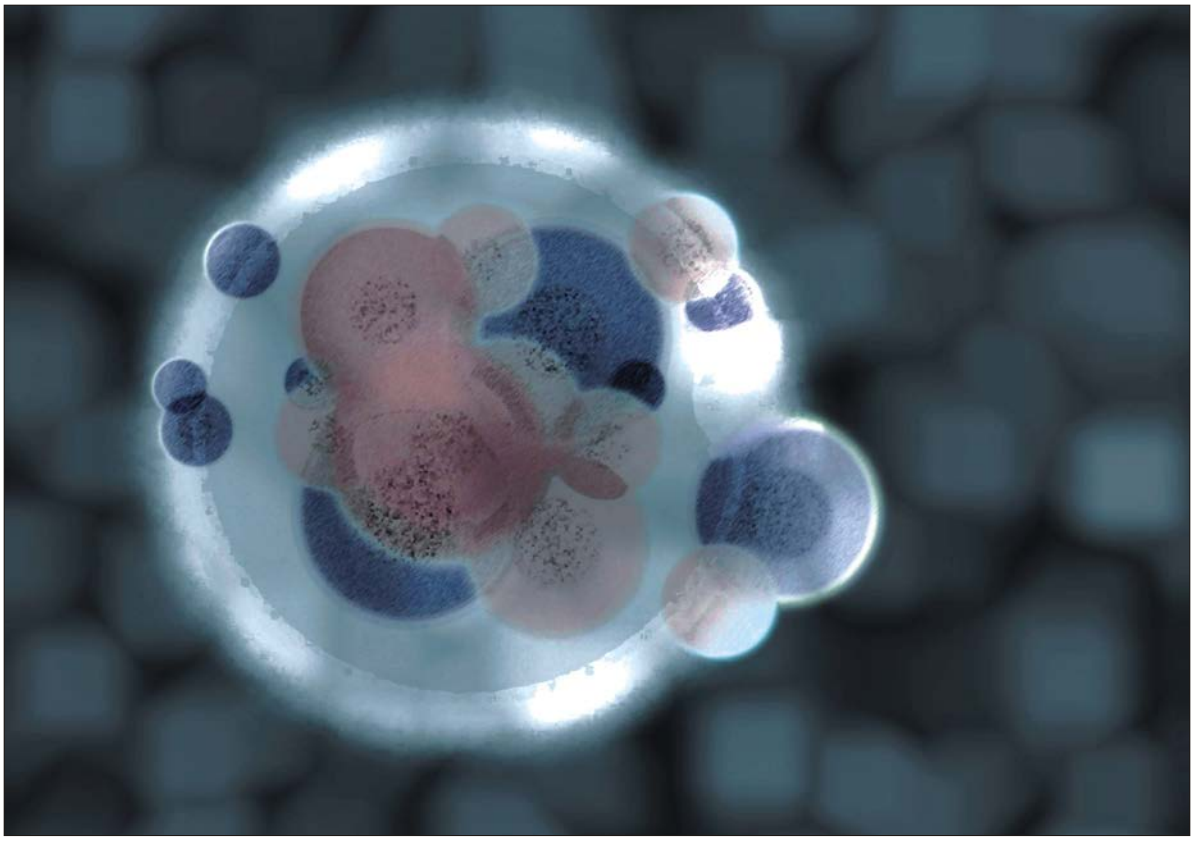

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# The Damage of Bark Beetles and the Relations Between Certain Tree Properties in Uludag Fir (*Abies nordmanniana* subsp. *bornmulleriana* Mattf.) at Ilgaz Mountain, Cankiri, Turkey

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**Abstract:** The damage of bark beetles in Uludag Fir (*Abies nordmanniana* subsp. *bornmulleriana* Mattf.) stands at Ilgaz Mountain, Cankiri and the relationships between height-diameter at breast height (DBH), crown diameter-DBH and crown diameter-height were also investigated in this study. Bark samples obtained from Uludag firs at various ages and dbh from study area which were pure Uludag fir stands, were brought to laboratory and determined bark beetles were identified. It was determined that the most common and harmful bark beetles were *Cryphalus piceae* (Ratz.) and *Ips* (*Pikyokteines*) *curvidens* (Germ.) in Uludag fir dominated stands of 50-100 age and 15-40 cm dbh. It is necessary that yearly outbreak area and intensity surveys should be conducted in order to minimize bark beetle damage. Five sample plots were selected from pure Uludag fir stands in study area and certain properties were measured on the living trees. After the regression analysis carried out, 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 Uludag firs. The strongest relationship determined was the crown diameter-height relationship ($R^2 = 0.959$), followed by the tree height-DBH ($R^2 = 0.844$) and crown diameter-DBH ($R^2 = 0.805$) relationships, respectively.

**Key words:** Bark beetles, uludag fir, crown diameter, DBH, tree height, regression analysis

## INTRODUCTION

Turkey has a diverse biological diversity due to her location between Europe and Asia that surrounded by seas at three sides, soil and topographic structure and various climatic zones. 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.

Uludag fir *(Abies nordmanniana* subsp. *bornmulleriana* Mattf.) is one of the endemic tree species in Turkey. Its distribution ranges in Black Sea region, from west of Kizilirmak river to Uludag Mountain and between 1000 and 2000 m elevations. Bolu, Kastamonu and Zonguldak provinces are inside of the optimum distribution area of this species (Genc, 2004).

In this study, Uludag fir is dominant species which is located at south aspects of Ilgaz Mountain at 1540-2040 m elevations and at "High Mountain Forest" level as compared to Alps in regards to forest and plant geography. High mountain forests have to survive against unfavorable and extreme environmental conditions. As a natural consequence, Uludag fir is under certain abiotic and biotic factors (i.e., insect outbreaks, unfavorable climatic conditions, storm and windfalls). Because of occurrences of bark beetle outbreaks and certain deficiencies in silvicultural practices fastening this process, solution of the problems increasingly becomes difficult. Thus, silvicultural practices and management of harmful insects in Ilgaz forests have a great importance.

According to previous studies, there is a close relationship between bark beetle damage on firs and dbh, crown diameter and age of stand, elevation and tree count in per ha (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.

There is a close relationship between tree parameters such as diameter, height, crown size and bole volume (Philip, 1994). Using these allometric relationships, a

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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, damage of bark beetles and the relationships between individual tree DBH, height and crown diameter were investigated in Uludag fir 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 Uludag fir stands of the research area were evaluated.

## MATERIALS AND METHODS

This study was carried out in order to determine the damage of bark beetles and the relationship between dbh, height and crown diameter of Uludag fir. The main materials of the study were Uludag firs and bark beetles. Other material were tape, calipers, heightmeter (Blume-leis), increment borer, GPS, clinometer, stereo-microscope, thermal jug and 1/25000 scaled stand types map.

The data used in the study were obtained from the natural pure Uludag fir stands at elevations between 1540-2040 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.

Bark samples obtained from firs at various ages and dbh were brought to laboratory in thermal jug and investigated under stereo-microscope and then determined insects were identified. Bark beetles were also caught by means of insect specific pheromone baited traps. Bark beetle sampling was carried out generally with weekly interval between 2000-2005. In addition, soil samples which represent study area were brought to laboratory and both physically and chemically analyzed.

Five sample plots were selected from the pure Uludag fir 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 Uludag firs in the sample plots 1, 2, 3 and 4 and 2 Scots pine (*Pinus sylvestris* L.) in addition to Uludag firs 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 Uludag fir 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 found by taking 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, 68, 82, 96 and 104, respectively.

Table 1: Some site characteristics of the sample plots

| Sample plot No. | Location | Elevation (m) | Aspect | Slope (°) | Relief |
|---|---|---|---|---|---|
| 1 | Kazanca | 1570 | North | 17 | Middle slope |
| 2 | Karanlikdag | 1710 | Northwest | 8 | Middle slope |
| 3 | Yukarigol | 1870 | Northwest | 29 | Upper slope |
| 4 | Taspinar | 1930 | Southeast | 17 | Upper slope |
| 5 | Yanik | 2010 | Northeast | 24 | Upper slope |

The regression analysis was applied to determine whether there was a statistical relationship between DBH, height and crown diameter in Uludag firs (Kalipsiz, 1981). The data of a total of N = 269 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 determined. 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). In all types of relationships, the first item was accepted as the independent and the second item was accepted as the dependent variable. All statistical analyses with a confidence level of p = 0.05 was used for statistical significance; and the analyses were carried out by using Minitab R13 package.

## RESULTS

**Bark beetles:** According to inspections on bark samples which obtained from Uludag fir trees in sample plots and around, 7 bark beetle species [(*Cryphalus piceae* (Ratz.), *Ips acuminatus* (Gyll.), *Orthotomicus erosus* (Woll.), *Pityogenes quadridens* (Hartig), *Ips (Pityokteines) curvidens* (Germ.), *Trypodendron lineatus* (Oliver) (Scolytidae); *Pissodes piceae* (Illig.) (Curculionidae)], were determined at stands of 15-40 cm dbh, 50-100 age, 35-100% slope, generally north and northwest aspects and at elevation of 1540-2040 m where firs dominated (Simsek, 2002).

**Soil analysis:** Soil texture of study area was sandy-clay (83%), 7.90-8.16 pH (slightly alkali and moderate alkali), rich in lime (56.95-85.52%) and poor in organic matter (3.93-1.20%).

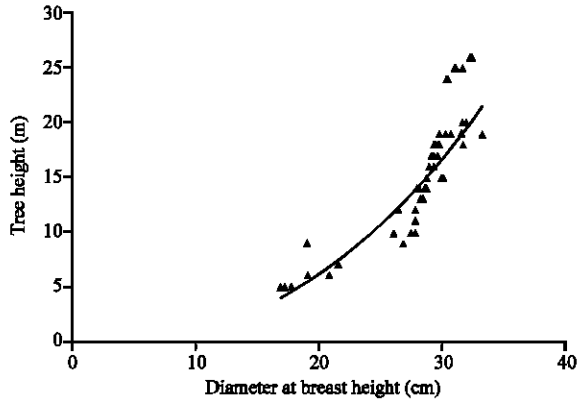


Fig. 1: The relationship between tree height and DBH

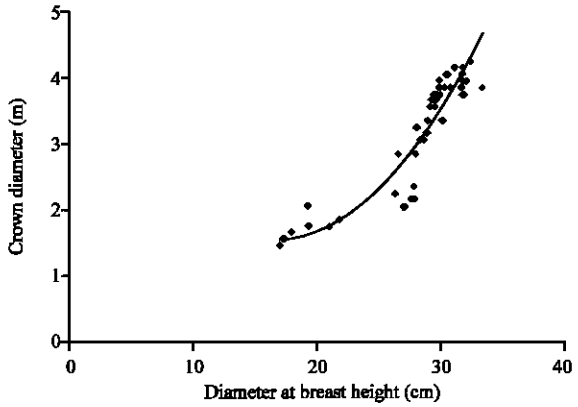


Fig. 2: The relationship between crown diameter and DBH

**Tree height-DBH relationship:** At the end of the regression analysis, it was determined that a power regression model established between these two variables was statistically significant ($F = 1399.73$; $p<0.001$). The regression equation was:

$$H = 0.0037 (DBH)^{2.474} \quad (1)$$

It was found that the coefficient of determination and the standard error of estimate were $R^2 = 0.844$ and $S_{H, DBH} = 0.157$, 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 tree height and DBH (Fig. 1). Because, DBH explained 84.4% of the observed variation in tree height.

**The crown diameter-DBH relationship:** The regression analysis showed that a second-degree regression model established between these two variables and it was statistically significant ($F = 531.44$; $p<0.001$). The regression equation was:

$$CD = 4.6200 - 0.3690 (DBH) + 0.0112 (DBH)^2 \quad (2)$$

It was found that the coefficient of determination and the standard error of estimate were $R^2 = 0.805$ and $S_{CD, DBH} = 0.3437$, respectively. The regression coefficients ($b_0$, $b_1$ and $b_2$) 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 80.5% of the observed variation in crown diameter.

**The crown diameter-tree height relationship:** The regression analysis showed that it was determined that a second-degree regression model established between these two variables and it was statistically significant ($F = 3041.89$; $p<0.001$). The regression equation was:

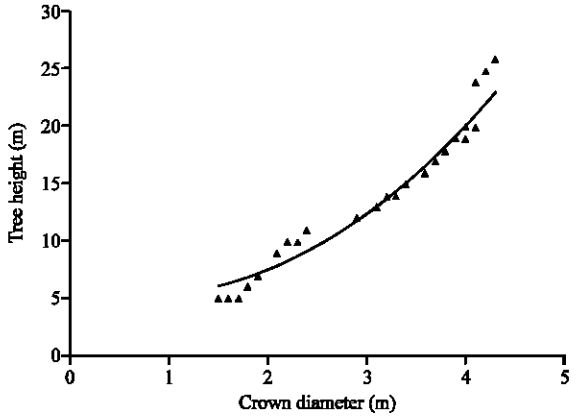


Fig. 3: The relationship between crown diameter and tree height

$$H = 6.35 - 2.27 (CD) + 1.43 (CD)^2 \quad (3)$$

It was found that the coefficient of determination and the standard error of estimate were $R^2 = 0.959$ and $S_{H, CD} = 0.9862$, respectively. The regression coefficients were also significant ($p<0.001$ for $b_0$ and $b_2$ and $p<0.005$ for $b_1$). Thus, it is seen that there is a strong positive, nonlinear relationship between crown diameter and tree height (Fig. 3). Because, the crown diameter explained 80.5% of the observed variation in tree height.

## DISCUSSION

Results of this study show that dbh of Uludag firs varied between 15-40 cm, ages of firs varied between 50 and 100, slopes of stands were high (35-100%), root systems were at the soil surface at shade aspects, Uludag firs were stressed as a result of poor soil quality at years

when precipitation was insufficient due to severe drought, firs were physiologically weakened due to tree roots' appearance at soil surface at landslide areas and there were many fallen trees due to various reasons. Therefore, soil structure of study areas mentioned above, negatively affects and stresses tree development. Thus, we reached the conclusion those areas where Uludag fir grows and specified conditions rule, are appropriate for bark beetles' breed. Results of previous 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 and Ozdemir, 2000; Simsek, 2000, 2001, 2002, 2003; Simsek and Oner, 2002; Tiberi, 1997; Toper, 2000; Tsankov *et al*., 1994; Yuksel, 1997; Witrylak, 1995) are similar to support our findings. In this study, 7 bark beetles have been determined, however, the most important pests of fir were determined as *C. piceae* and *P. curvidens*.

It was determined that the regression models established between DBH, height and crown diameter variables of Uludag firs 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 ($R^2 = 0.959$), followed by the tree height-DBH ($R^2 = 0.844$) and crown diameter-DBH ($R^2 = 0.805$) relationships, respectively. The tree height-DBH relationship was stronger than the crown diameter-DBH relationship.

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 power regression model.

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 second-degree polynomial 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 the second-degree polynomial model as in the crown diameter-DBH relationship.

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 Uludag fir stands of the research area. The crown diameter-tree 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 relationship can be described by the power model ($Y = b_0X^{b1}$), while the crown diameter-DBH and crown diameter-height relationships can be described by the second-degree polynomial model ($Y = b_0 + b_1X + b_2X^2$) in Uludag firs of the research area.

Finally, infestation of healthy firs by bark beetles may be prevented by means of removal of infected trees and slash in regard to bark beetle bioecology and stand structure of Uludag firs in the research area. Cutting/trapping/removal processes should be repeated in this type of control. We accept that keeping the pest density under the economic threshold level is possible by means of pheromone baited traps. However, in order to achieve this, dimensions and intensity of the pest outbreak should be determined by yearly surveys. All these studies had better to be completed between May and August in Ilgaz due to the great importance of application of both silvicultural and biotechnical methods.

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