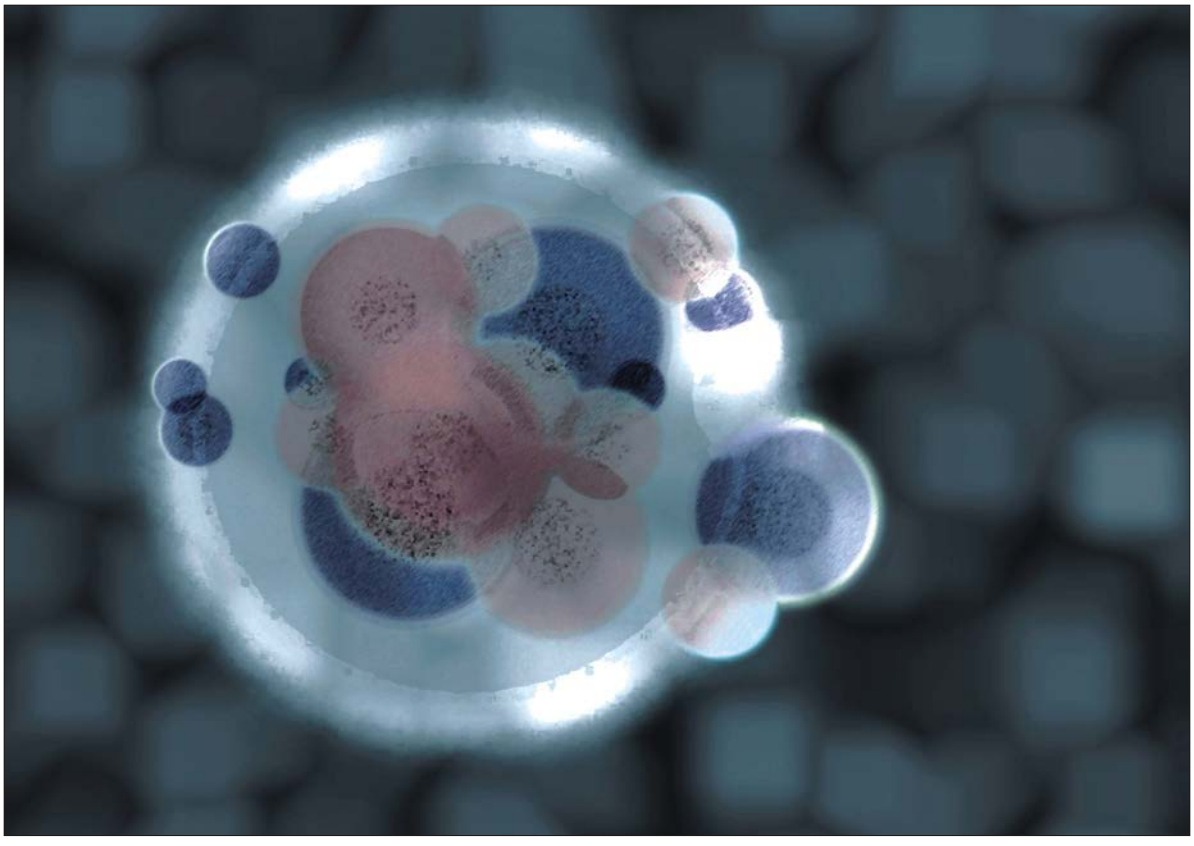

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The Relationships between Diameter at Breast Height, Tree Height and Crown Diameter in Calabrian Pines (*Pinus brutia* Ten.) of Baskonus Mountain, Kahramanmaras, Turkey

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Abstract: In this study, the relationships between height-diameter at breast height (DBH), crown diameter-DBH and crown diameter-height were investigated in Calabrian pines (*Pinus brutia* Ten.) of Baskonus Mountain, Kahramanmaras. Four sample plots were selected from pure Calabrian pine stands and DBH, height and crown diameter were measured on the live Calabrian pine trees, of which DBH was ≥4 cm, in these sample plots. At the end of the regression analysis carried out on the data of a total of 134 trees, it was determined that there were statistically significant ($P<0.0001$) and strong ($R^2>0.50$) relationships between DBH, height and crown diameter variables in Calabrian pines. The strongest relationship determined was the height-DBH relationship ($R^2=0.82$), followed by the crown diameter-DBH ($R^2=0.74$) and crown diameter-height ($R^2=0.62$) relationships, respectively. The results of the study indicated that the height-DBH relationship can be described by the second-degree polynomial model, while the crown diameter-DBH and crown diameter-height relationships 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 Calabrian pines of the research area.

Key words: Crown diameter, diameter at breast height, *Pinus brutia*, regression analysis, tree height

INTRODUCTION

Calabrian pine (*Pinus brutia* Ten.) is an economically valuable forest tree species of Turkey. Its widest distribution occurs in Turkey[1]. It is located in western Anatolia, southern Anatolia, Thrace and partly northern Anatolia[2] and pure Calabrian pine forests cover an area of about 3.1 million ha in Turkey[3]. Calabrian pine is a species, which is tolerant to high temperatures, drought and poor soil conditions and grows fast. Therefore, large plantations of Calabrian pine have been established especially in the Mediterranean climatic areas of Turkey.

Diameter at breast height (DBH), tree height and crown diameter are important tree characteristics. It is necessary to measure DBH and height in forest inventory studies and DBH, height and crown diameter in stand structure determination studies. DBH is a variable of which measurement is easy. Measurement of height and crown diameter variables is more difficult and time consuming than that of DBH. On the other hand, there is a close relationship between tree parameters such as diameter, height, crown size and bole volume[4]. Using these allometric relationships, a dimension of which measurement is difficult can be estimated by means of other dimensions which can easily be measured[5]. As a matter of fact, using the height-DBH relationship, heights can be estimated by means of DBHs[6,7]. Thus, the studies of forest inventory and stand structure determination can be made easier and at less cost.

In this study, the relationships between individual tree DBH, height and crown diameter were investigated in Calabrian pines in the forests of Baskonus Mountain, Kahramanmaras. 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 Calabrian pine stands of the research area were evaluated.

MATERIALS AND METHODS

The data used in the study were obtained from the natural pure Calabrian pine stands in the Baskonus Mountain. Baskonus Mountain is located in the central district of the Kahramanmaras province and its summit has an elevation of 1779 m. Mediterranean climate and Mediterranean mountain climate are seen at lower and upper elevations of the mountain, respectively. Four

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Table 1: Some site characteristics of the sample plots

Sample plot no.	Location	Elevation (m)	Aspect	Slope (°)	Relief
1	Kireclik	970	Northwest	22	Middle slope
2	Kireclik	1000	West	28	Middle slope
3	Koccagiz	1150	East	35	Middle slope
4	Rahmacilar	1160	Southeast	29	Upper slope

sample plots were selected from the pure Calabrian pine stands, which had a normal structure, in the direction perpendicular to the contour lines. The sample plots 1, 2 and 4 were 10x50 m and the sample plot 3 was 10x25 m dimensions. There were only Calabrian pines in the sample plots 1, 2 and 3; and 3 cedars of Lebanon (*Cedrus libani* A. Rich.) and 2 kermes oaks (*Quercus coccifera* L.) in addition to Calabrian pines in the sample plot 4. Some site characteristics of the sample plots are given in Table 1.

DBH, height and crown diameter of the live Calabrian pine trees, of which DBH was ≥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 68, 72, 48 and 44, respectively.

The regression analysis was applied to determine whether there was a statistical relationship between DBH, height and crown diameter in Calabrian pines[8]. The data of a total of N=134 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 ($S_{y.x}$)[9]. In all statistical analyses, a confidence level of P=0.05 was used for statistical significance; and the analyses were carried out by using SPSS 11.0 package.

RESULTS

The height-DBH relationship: In this relationship, diameter at breast height (DBH) and tree height (H) were taken as the independent and dependent variables, respectively. At the end of the regression analysis, it was determined that the second-degree regression model established between these two variables was statistically

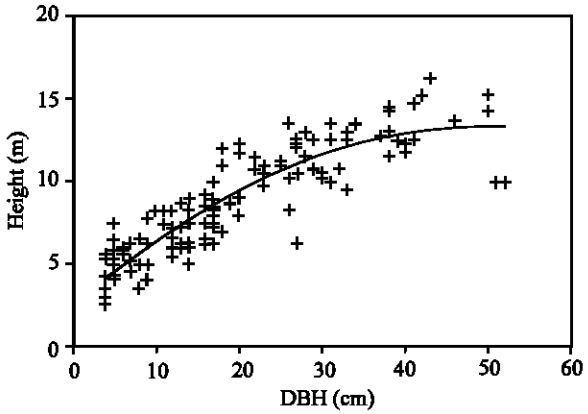

Fig. 1: The relationship between height and DBH

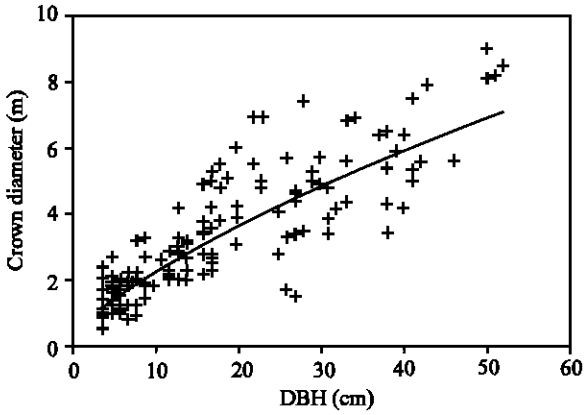

Fig. 2: The relationship between crown diameter and DBH

significant (F=298.08; P<0.0001). The regression equation was:

$$H=2.40 + 0.45(DBH) - 0.0045(DBH)^2 \quad (1)$$

It was found that the coefficient of determination and the standard error of estimate were R^2=0.82 and $S_{y.x}$=1.43, respectively. The regression coefficients (b_0, b_1, b_2) were also statistically significant (P<0.0001). Thus, it is seen that there is a strong positive, nonlinear relationship between height and DBH (Fig. 1). Because, DBH explained 81.98% of the variation observed in height.

The crown diameter-DBH relationship: In this relationship, diameter at breast height (DBH) and crown diameter (CD) were taken as the independent and dependent variables, respectively. At the end of the regression analysis, it was determined that the power regression model established between these two variables was statistically significant (F=372.37; P<0.0001). The regression equation was:

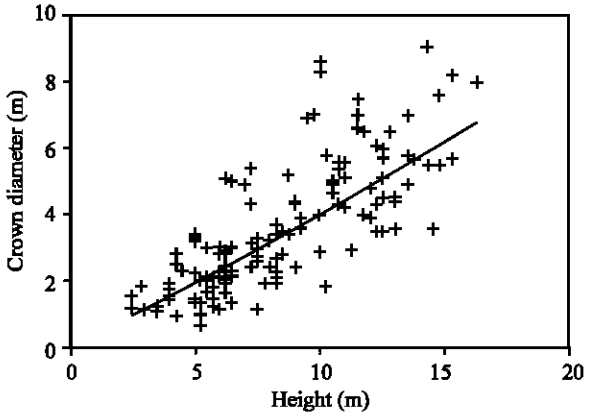

Fig. 3: The relationship between crown diameter and height

$$CD=0.49(DBH)^{0.68} \quad (2)$$

It was found that the coefficient of determination and the standard error of estimate were $R^2=0.74$ and $S_{yx}=0.31$, respectively. The regression coefficients (b_0, b_1) were also statistically significant ($P<0.0001$). Thus, it is seen that there is a strong positive, non-linear relationship between crown diameter and DBH (Fig. 2). Because, DBH explained 73.83% of the variation observed in crown diameter.

The crown diameter-height relationship: In this relationship, height (H) and crown diameter (CD) were taken as the independent and dependent variables, respectively. At the end of the regression analysis, it was determined that the power regression model established between these two variables was statistically significant ($F=216.11$; $P<0.0001$). The regression equation was:

$$CD=0.33\ (H)^{1.08} \quad (3)$$

It was found that the coefficient of determination and the standard error of estimate were $R^2=0.62$ and $S_{yx}=0.37$, respectively. The regression coefficients (b_0, b_1) were also statistically significant ($P<0.0001$). Thus, it is seen that there is a strong positive, nonlinear relationship between crown diameter and height (Fig. 3). Because, height explained 62.08% of the variation observed in crown diameter.

DISCUSSION

It was determined that the regression models established between DBH, height and crown diameter variables of Calabrian pines in the research area were statistically significant ($P<0.0001$). That the R^2 value is more than 0.50 in the models established indicates that there are strong relationships between these three variables[8]. The strongest relationship determined was the height-DBH relationship ($R^2=0.82$), followed by the crown diameter-DBH ($R^2=0.74$) and crown diameter-height ($R^2=0.62$) relationships, respectively. The crown diameter-DBH relationship was stronger than the crown diameter-height relationship.

The relationships between height and DBH were investigated in many studies[10-15]. 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[5] 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. Similarly, Demirci and Gul[11] determined that there was a strong relationship between height and DBH, described by a second-degree polynomial, in Calabrian pines of Kizilirmak Basin ($R^2=0.71$-0.86).

There are many studies investigating the relationships between crown diameter and DBH[10,16-19]. Francis[20] and Foli *et al.*[21] 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. Sun[16] also determined that there was a strong, positive exponential relationship between crown diameter and DBH ($R^2=0.94$) in Calabrian pine.

On the other hand, Hasenauer[18] 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 power 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 Calabrian pine stands of the research area. The crown diameter-DBH relationship, which is stronger than the crown diameter-height relationship, should be used in the estimate of crown diameter. In addition, the height-DBH relationship can be described by the second-degree polynomial model ($Y=b_0 + b_1X + b_2X^2$), while the crown diameter-DBH and crown diameter-height relationships can be described by the power model ($Y=b_0X^{b1}$) in Calabrian pines of the research area.

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