The Change of Diameter Increment Percentage in Even-Aged and Pure Oriental Spruce (*Picea orientalis* (L.) Link.) Stands by Age and Diameter Classes

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***Abstract**:*

Trees of diameter increment are known to vary according to the time and the site quality. In this study, we investigated instead of diameter increment for its proportionate percentage of the diameter increment by diameter and age classes. In this analysis, 204 sample plots data were used in the even-aged and pure oriental spruce stands. To examine the percentage change in age classes and diameter classes, the mean values of the 1011 measured diameter and age is used. As a result of a regression analysis, the relationship between the percentage of diameter increment and age classes was found to be about 95%. The relationship between diameter increment percentage and diameter classes was determined about 92%. Both are based on mathematical models derived from the relationship.

Key Terms: Oriental Spruce, Diameter increment percentage, Age classes, Diameter classes

Introduction:

Oriental Spruce which has natural distribution in coastal region of Northeast Anatolia and Caucasia starts from Turkey-Georgia border in our country and finishes at Melet River in the West of Ordu (Anşin and Özkan, 1993). They form mixed stands sometimes with pure and mostly with tree species such as Scotch Pine (*Pinus sylvestris)*, Fir (*Abies nordmanniana)* and Beech (*Fagus orientalis)* in the hillsides of Black Sea mountains facing the sea. With the main distribution, they cover 289397 ha area in total 146300 ha being pure at 1100-2000 m altitude (URL 2010). In addition to this, in the areas which are under the effect of Çoruh River and Harşit Stream enabling humid sea winds to be carried inwards behind Black Sea Region, they are found either pure or mixed in the northern hillsides of high mountains (Anşin, 1981).

Oriental Spruce is distributed in 94902,5 ha area in total within the borders of Artvin Regional Directorate of Forestry. 14260,9 ha of this area is pure Oriental Spruce stands and distributed within the borders of Artvin, Şavşat and Ardanuç Forest Sub-district Directorates. Regional Directorate of Forestry composes 25% of forestland and 35% of forestland in Eastern Black Sea Region (Kırış and Özdemir 2005).

Diameter increment varies according to the species, social environment of tree, site quality and time. Diameter increment of trees is the indicator of their growth. At the same time, diameter increment is also an important input used in calculation of volume increment of tree. Diameter increment of trees with same diameter can be different; likewise diameter increment of trees with different age can be different as well. Diameter increment can be with or without bark. The most practical ones in increment without bark and based on the sum of period end diameter measurement annual tree ring formed during period years determined with increment borer. In the comparison of diameter growth of trees, it would be beneficial for planners to give diameter increment together with diameter increment percentage which is the proportional growth of it. Diameter increment percentage is known as diameter without bark. However, in diameter measurements bark is also included in the process. Therefore bark thickness of tree should be determined before measurement and diameter increment percentages should be calculated after diameter with bark is excluded.

It is known that diameter increment decreases according to tree diameter and age in the

sense of amount. It is estimated that diameter increment percentage would have similar change. In this study it was especially emphasized on mathematical statement of change in the diameter increment percentage depending on time and diameter of trees. On the other hand, future diameter of a Spruce tree will be estimated using equations obtained as a result of the study.

Material and Method:

In this study, 204 sample plot data were used which are obtained from pure Oriental Spruce (Picea orientalis (L.) Link) stands within the Artvin Regional Directorate, Artvin and Ardanuç Forest District Directorates. Sample plots are determined randomly in 1000 m2 size and (50x20m) rectangular shape. In each sample plot; diameter at breast height (which are greater than 4 cm), in each diameter step age and ring thickness in recent ten years were measured through increment borer obtained from breast height of at least one tree. The number of trees whose increment borer is obtained is 1011 in total. Various statistical information are given about measurements in Table 1.

Table 1. Various statistical information about measurements

	N	Minimum	Maximum	Average	Standard Deviation
Diameter (cm)	1.011	6,7	60,5	34,02	9,09
Age (year)	1.011	33	193	95,82	25,10
Thickness of Ten Rings (mm)	1.011	1	40	11,03	4,99

In the calculation of diameter increment percentage for each tree, Pressler formula was used which is given below. Here; *b* is ring thickness in the recent 10 years; *n* is the number of period years (10 years); *ds* is the last diameter without bark.

$$P_d = \frac{200.b}{n.d_s} \qquad (1)$$

Diameter classes starts from 4 cm and formed in 4 cm width. The average of diameter of all trees within diameter grade width was obtained and average value was attained for each diameter grade. Age classes were formed in 10 years. Age average of trees included within age classes width were obtained and single value was calculated for each age class. Trees were distributed according to Diameter and age classes after 10-year increment were measured and the average of increment was obtained. Diameter increment percentages according to Diameter classes were given in Table 2, diameter increment percentages according to age classes were given in Table 3. In order to analyze change of diameter increment percentage in Diameter and age classes; these average values were analyzed with Correlation Analysis in SPSS package program for the existence of relation between data then exposed to Regression Analysis for the statement of this relation through mathematical model. In regression analysis, compatibility of these data with Logarithmic, Inverse and Quadratic Polynomial models were analyzed. General equations of models are given below.

Logarithmic model;
$y = b_0 + b_1.ln(x)$

Inverse model;
$y = b_0 + b_1/x$

Quadratic polynomial;
$y = b_0 + b_1.x + b_2.x^2$

Here; y (dependent variable), represents diameter increment percentage; x (independent variable) represents average diameter of diameter class and average age of age class.

Table 2. Diameter increment percentages according to Diameter classes

Mean of diameter class	Average diameter (cm) $\bar{d}$	Average Diameter Increase Percentage (%) P_d
6	6,70	3,08
10	11,07	2,25
14	14,09	1,67
18	18,46	1,12
22	22,13	0,93
26	26,05	0,82
30	29,84	0,71
34	33,77	0,67
38	37,75	0,64
42	41,60	0,67
46	45,60	0,61
50	49,83	0,60
54	54,06	0,63
58	57,80	0,50
62	60,50	0,35

Table 3. Diameter increase percentages according to age classes

Age Classes	Average Age (Year) t	Average Diameter Increase Percentage (%) P_d
30 - 40	36	1,91
40 - 50	45	1,24
50 - 60	55	1,12
60 - 70	65	0,94
70 - 80	74	0,84
80 - 90	85	0,72
90 - 100	95	0,69
100 - 110	104	0,65
110 - 120	114	0,63
120 - 130	124	0,59
130 - 140	134	0,62
140 - 150	144	0,54
150 - 160	153	0,47
160 - 170	162	0,50
170 - 180	171	0,43
180 - 190	186	0,54
190 - 200	193	0,41

Results and Discussion:

Data obtained as a result of measurements at 204 different plots of even-aged and pure Oriental Spruce stands in Artvin and Ardanuç Forest District Directorates were arranged according to diameter and age classes. It was analyzed with Pearson Correlation Analysis whether there is a separate relation between diameter increment percentage and diameter and age classes. As a result of analysis, it was determined that as the diameter and age classes increase diameter increment percentage decreases and there is a negative relationship.

For the statement of this relation between diameter increment percentage diameter and age classes through mathematical models, Regression Analysis (curve estimation) was carried out. Here, available and common models in SPSS package program were used as mathematical model. As a result of the analysis, it was understood that the relation between diameter increment percentage and both diameter and age classes can be stated with Inverse model. This model has the highest correlation coefficient and the lowest standard deviation within other models.

Average Diameter of Diameter Class– Diameter Increment Percentage Relation:

As it is in Table 2, diameter increment percentage of trees decreases as diameter of trees increases. Pearson Correlation analysis was carried out in order to analyze whether this nominal change is statistically significant or not (Table 4). As a result of the analysis, it was found that there is a negative relation between diameter increment percentage and diameter grade average diameter (p=0,00).

Table 4. Correlation analysis table for diameter increment percentage and diameter class average diameter

		$\bar{d}$	P_d
$\bar{d}$	Pearson Correlation	1	-,807(**)
	Sig. (2-tailed)		,000
	N	15	15
P_d	Pearson Correlation	-,807(**)	1
	Sig. (2-tailed)	,000	
	N	15	15

****** : Correlation is significant at %1 level.

Regression Analysis was carried out for mathematical statement of negative relation between diameter increment percentage and diameter class average diameter. For this aim, Logarithmic, Inverse and Quadratic Polynomial equations were tested in SPSS package program. Diameter increment percentage was dependent variable and diameter class average diameter was independent variable in the regression analysis. Brief information about analysis results and parameter values were given in Table 5; graphic for the models was given in Figure 1.

Table 5. Brief information about analysis and parameter values

	Model Summary					Parameter Values		
Equations	R^2	F	SD1	SD2	p	Constant	b1	b2
Logarithmic	0,877	93,021	1	13	0,000	4,628	-1,075	
Inverse	0,977	557,632	1	13	0,000	0,116	20,571	
Quadratic Polynomial	0,897	52,490	2	12	0,000	3,465	-0,134	0,001

SD: Degree of Freedom

As it is seen in the table; the relation between diameter increment percentage and diameter class average diameter can be explained with Inverse model best (R^2=0,98 and p=0,000). Mathematical statement of the relation between diameter increment percentage and diameter class average diameter was given according to Inverse model.

$$P_d = 0{,}116 + 20{,}571/\bar{d}$$

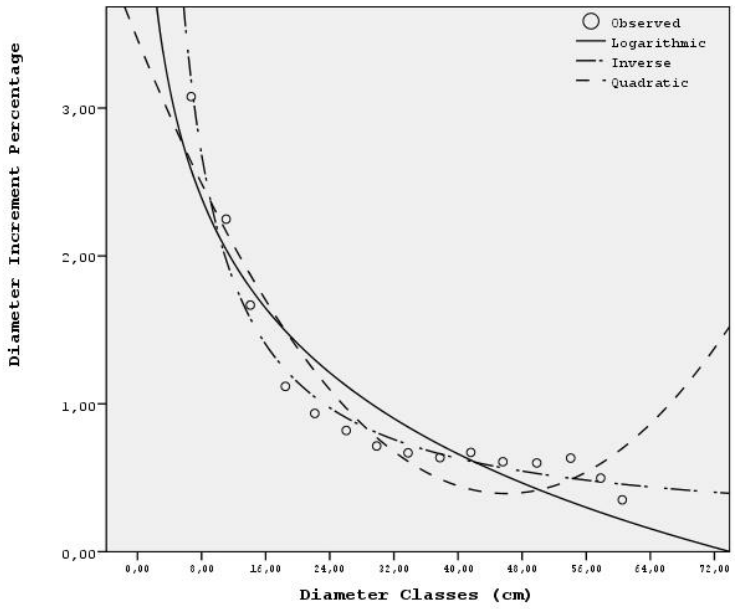

Figure 1.Graphic about analyzed models

Average Age of Age Class – Diameter Increment Percentage Relation:

As it is seen in Table 3, there is a decrease in diameter increment percentages as the age of trees increase. Pearson Correlation analysis was carried out in order to analyze whether this nominal change is statistically significant or not (Table 5). As a result of the analysis, it was found that there is a negative relation between diameter increment percentage and diameter class average diameter (p=0,00).

Table 5. Correlation analysis between diameter increment percentage and age class average age

		$\bar{t}$	P_d
$\bar{t}$	Pearson Correlation	1	-,830(**)
	Sig. (2-tailed)		,000
	N	17	17
P_d	Pearson Correlation	-,830(**)	1
	Sig. (2-tailed)	,000	
	N	17	17

****** : Correlation is significant at %1 level.

Regression Analysis was carried out for mathematical statement of negative relation between diameter increment percentage and average age of age class. For this aim, Logarithmic, Inverse and Quadratic Polynomial equations were tested in SPSS package program. Diameter increment percentage was dependent variable and average age of age class was independent variable in the regression analysis. Brief information about analysis results and parameter values were given in Table 7; graphic for the models was given in Figure 2.

Table 7. Brief information about analysis and parameter values

	Model Summary					Parameter Values		
Equations	R^2	F	SD1	SD2	p	Constant	b1	b2
Logarithmic	0,848	83,770	1	15	0,000	3,942	-0,689	
Inverse	0,955	322,049	1	15	0,000	0,112	57,815	
Quadratic Polynomial	0,880	51,558	2	14	0,000	2,313	-0,024	7,76E-05

SD: Degree of Freedom

As it is seen in the table; the relation between diameter increment percentage and average age of age class can be explained with Inverse model best (R^2=0,96 and p=0,000). Mathematical statement of the relation between diameter increment percentage and average age of age class was given according to Inverse model.

$$P_d = 0{,}112 + 57{,}815/\bar{t}$$

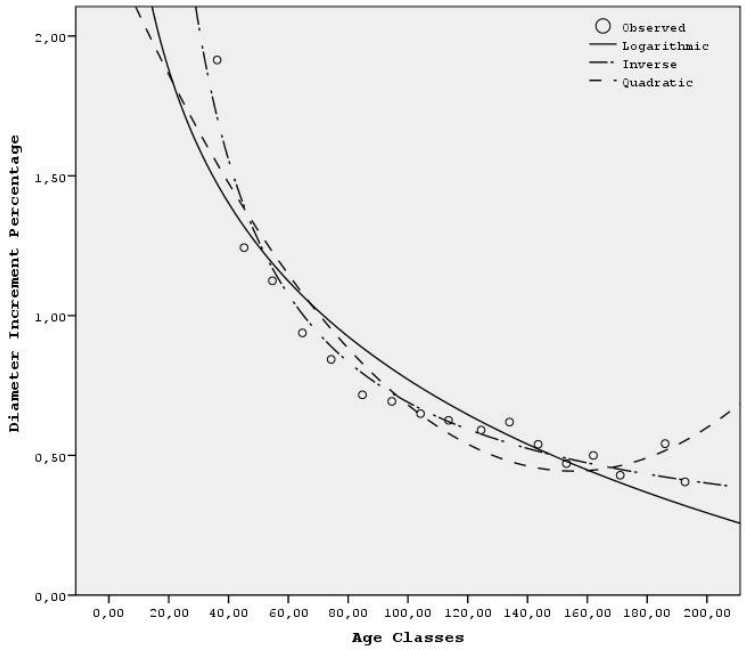

Figure 2.Graphic about analyzed models

Acknowledgment:

In this study data obtained within the scope of project code TOVAG-109O603 which was supported by TÜBİTAK. I would like thank to project team and workers.

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