# Factors Affecting the Success of Natural Regeneration in Oriental Beech (*Fagus orientalis* Lipsky) Forests in Turkey

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**Abstract –** The success of natural regeneration using the Uniform Shelterwood Method (USM) was determined in an oriental beech (*Fagus orientalis* Lipsky.) stand, in the Bartın-Sökü Forest Range District. Number, height growth and root collar diameter of seedlings were investigated in the 10 experimental plots in the 5.0 ha regeneration area for 7 years (2004–2010). According to the result of factor analyses, it was found that amount of filled seeds, soil cover, growth status of seed trees, stand canopy closure, average crown projection area of seed trees, amount of organic substance in the upper soil layer, soil reaction in the upper soil layer and hillside status were the most effective factors determining the success of natural regeneration.

**Oriental beech *(Fagus orientalis* Lipsky.*)* / natural regeneration / factor analysis / silviculture**

## 1 INTRODUCTION

Because of variable climate and physiographic conditions, Turkey has natural forest resources with high biological and economic value both with respect to tree species and area. According to 2006 data, forest area of the country is 21.2 million hectares, reaching 27.2% of the total area. 50% of it is degraded and coppice forest. The improvement of this situation and the increase of forestry sector's portion in national income depend largely on successful regeneration practices. Oriental beech (*Fagus orientalis* Lipsky.) has the fourth largest distribution area with 1.7 million ha. Total volume of beech forests is 263.772.103 $m^3$, with a total annual increment of 6.130.147 $m^3$ (OGM 2006).

## 2 MATERIAL AND METHOD

### 2.1 Material

Forests of the Sökü district are situated in the *Northwest Euxinic* forest subzone of the *Euxinic* forest zone (Mayer – Aksoy 1998). According to inventory data for 2000, total forest area in the region is 3386.0 ha, 6.2% (208.5 ha) of it is degraded forest. Sökü region is under the effect of West Black Sea sub-climate (IIc). All seasons are rainy, the month with highest

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average precipitation is December (162.3mm), the one with the lowest is May (88.0mm). Annual average temperature is 10.6 °C, the coldest month is January (0.0 °C), and the hottest are July (19.8 °C) and August (19.7 °C). Vegetation period in the research area is 6 months (May–October). General soil type is stony, alkaline, sandy clay and sandy clayish mud of mediocre depth (OGM 2001, OGM 2002).

In compartment 27a, a pure beech stand of 5.0 hectares, a regeneration cut using the Uniform Shelterwood Method (USM) has been performed in 2003, in a seed year. During the cut the stand canopy closure has been reduced to 0.6–0.7. Tending of seedlings was continued for 3 years. To follow the increased light demand of seedlings, the canopy closure has been reduced to 0,5 in 2007. A total of 10 experimental plots with the size of 25 x 40 m have been established to follow up the regeneration process.

## 2.2 Method

At first, predominant habitat conditions (climatic, edaphic and physiographic factors such as exposure, slope, altitude and hillside situation) in the experimental plot have been determined. Regarding soil conditions, soil depth, structure type and rooting depth, as well as soil reaction (pH), amount of organic substances, nitrogen, phosphor and potassium have been determined. In addition, in each plot thickness of organic cover (litter and humus layers) and crown cover have been measured. For the seed trees in the 10 experimental plots, age, number, diameter, height, basal area, volume, average annual volume increment, crown width and crown projection area have been determined.

The most important criterion in determining the success of natural regeneration practices is the number of plants per square meter (Saatçioğlu 1979, Atay 1987, Nyland 2002). Not only changes in the number of seedlings but also changes in their height and the root collar diameter per year have been examined. For this purpose, 5 x 5 m sample plots were made up in the 25 x 40 m parcels. In 20 sample plots tally of seedlings, height (cm) and the root collar diameter (mm) measurements were established annually during the seven year research (2004–2010).

## 2.3 Statistical Analysis

SPSS (Statistical Package for Social Science) 9.0 pack program was used for the statistical analysis of data. Kolmogorov-Smirnov test has been applied to determine whether the data displayed normal distribution.

First, correlation analysis has been applied for the purpose of determining the degree of mutual relation between variables and direction. As a result of analysis, dual linear coefficient of correlation between factors have been examined whether they are meaningful or not in the level of significance 0.05 and 0.01. Factor analysis has been applied according to the coefficient of correlation between factors. The Principal Component Analysis has been applied to detect the factors explaining the variance best. “Kaiser” and “Scree Test” criterions are used mostly in determining the number of factors which will represent the relations between variables in the highest degree. In this research, the Kaiser criterion – considering the factors with eigenvalue (joining amount to variance) statistics greater than 1 – was used.

In terms of simplifying the interpretation, unturned factor matrix obtained with Principal Component Analysis should be subjected to rotation. For this purpose, the *Varimax* technique has been applied and a converted factor matrix was obtained by the selection of orthogonal rotation which takes interfactor zero correlation as basis. Interpretation and naming of factors has been made on basis of the variables with high factoral load. In some cases common reasons underlying the variables relating to factors have been taken into consideration. In the research for 7 years, the main aim was to clarify the effects of variables (climatic, edaphic and physiographic and variables relating to seed trees and seedlings) on the number of seedlings.

In this regard, the last three years (2008, 2009 and 2010) data of climate, state of weed and litter cover was used for impact of these variables determined on success of natural regeneration in recent years. For this purpose, multiple regression analysis was carried out in order to determine the effects of all investigated variables on seedling number. The number of beech seedlings per square meter in 2010 has been taken as dependent variable. In multiple regression analysis, the most important factors appeared as independent variables.

## 3 RESULTS AND DISCUSSION

### 3.1 Number of Seedlings

The success of natural regeneration practices is determined by the regrowth per square meter. Numbers of the last tally carried out in regeneration plots in 2010 is shown in *Figure 1*.

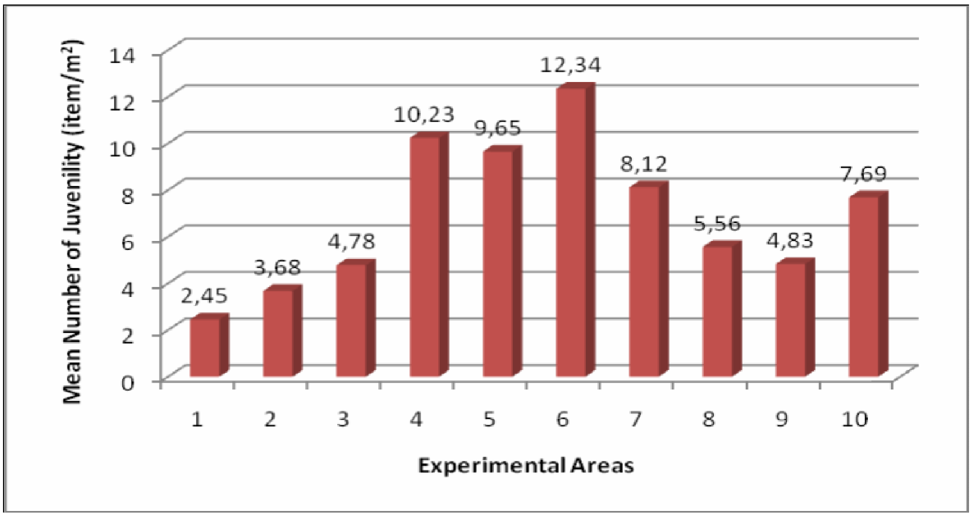


*Figure 1. Mean numbers of oriental beech juvenilities according to experimental areas*

The number of oriental beech seedlings ranged from 2.45 to 12.34 per $m^2$. In a study of beech natural regeneration practices in the Belgrade Forest, the average seedling number ranged between 4 and 80 plants/$m^2$ in the 3rd year and between 4 and 56 plants/$m^2$ in the 5th year (Saatçioğlu 1970). In Turkish practice, seedling numbers of 2–64 plants/$m^2$ at the end of 1st year, 1–57 plants/$m^2$ at the end of 2nd year and 2–71 plants/$m^2$ at the end of 3rd year are reported (Suner 1978). In the Bartın-Yenihan Forest Range District's 70b compartment, in a study of beech natural regeneration, recruitments between 8 plants/$m^2$ and 29 plants/$m^2$ at the end of 1st year, 7 to 28 plants/$m^2$ at the end of 2nd year and 6 to 26 plants/$m^2$ at the end of 3rd year were counted (Özel et al. 2009).

When seedling numbers in the present study are compared to other beech natural regeneration practices done with USM, the natural regeneration appears to be unsuccessful. Based on the count in 2010, it looks that 2003 was not a good seed year just a mediocre one in the Bartın-Sökü district. However, one of the reasons why the seedling number is low is that the weed control and soil cultivation in 2003 were not carried out intense enough and with appropriate technique. It was found that the density of weed cover, particularly that of pontic rhododenron (*Rhododendron ponticum* L.) presents an important problem for natural and artificial practices of regeneration in beech. In order to eliminate this problem, clearing of the regeneration area is necessary to remove particularly pontic rhododenron (Saatçioğlu 1970, Kharitonenko 1972, Suner 1978, Eşen 2000).

## 3.2 Height Growth

Average annual height growth of beech seedlings are shown in *Figure 2*. The mean height of 7 years old seedlings, ranged from 14.8 cm to 17.3 cm. In the Belgrade forest, oriental beech seedlings' average height ranged between 13.5 cm and 20.9 cm in the 3rd year, 13.8 cm to 23.0 cm in the 4th and 17.3 cm to 46.6 cm in the 5th (Saatçioğlu 1970). Generally, the height growth of beech seedlings in the Sökü regeneration area is found to be satisfactory.

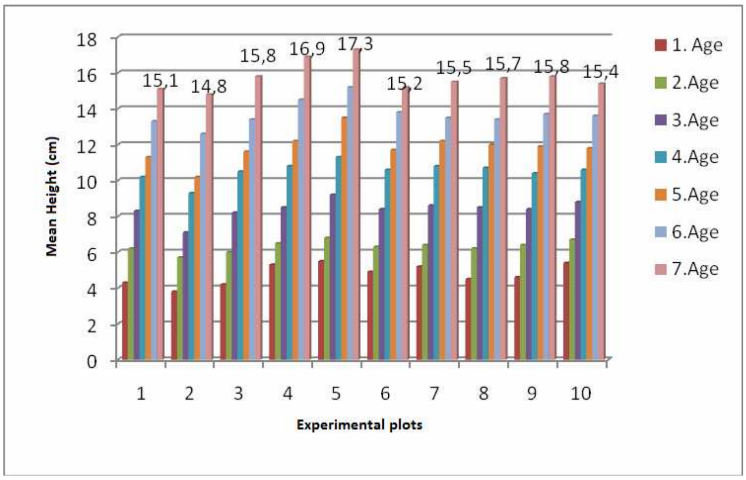


*Figure 2. Mean heights of oriental beech seedlings in experimental plots*

## 3.3 Root Collar Diameter Development

The root collar diameter growth of seedlings is shown in *Figure 3*. The mean root collar diameter of 7 years old seedlings, ranged from 18.5 mm to 21.3 mm.

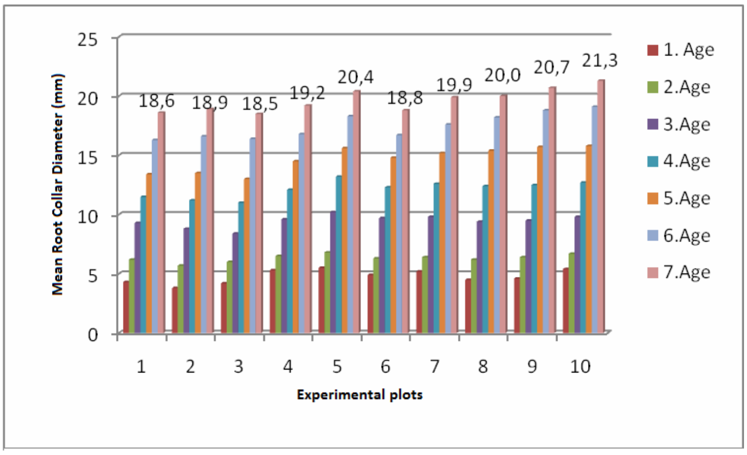


*Figure 3. Mean root collar diameter of oriental beech seedlings in experimental plots*

In another research in the Düzce, Cide and Akkuş regions, average root collar diameter after removal cut ranged between 15.8 mm and 23.5 mm (Suner 1978). According to this data, the beech seedlings' root collar diameter growth in the research area is found to be satisfactory too.

## 3.4 Factors Affecting the Regeneration Success

Factor analysis has been applied in order to determine factors that can be effective in the success of regeneration. For this purpose 52 variables were put in the analysis (*Table 1*).

*Table 1. Names, dimensions and labels of investigated variables*

| Order | Variables | Dimension | Label |
|---|---|---|---|
| 1 | Altitude of Experimental Plot | m | AEA |
| 2 | Exposure of Experimental Plot | --- | EEA |
| 3 | Slope of Experimental Plot | % | SEA |
| 4 | Hillside Status of Experimental Plot | --- | HSEA |
| 5 | Average Diameter of Beech Seed Trees in Experimental Plot | cm | AD |
| 6 | Average Height of Beech Seed Trees in Experimental Plot | m | AH |
| 7 | Age of Beech Seed Trees in Experimental Plot | Year | ABST |
| 8 | Average Crown Form of Beech Seed Trees in Experimental Plot | --- | ATF |
| 9 | Average Trunk Form of Beech Seed Trees in Experimental Plot | --- | ABF |
| 10 | Number of of Beech Seed Trees | trees/ha | NBST |
| 11 | Average Volume of Beech Seed Trees | $m^3$/ha | AV |
| 12 | Average Annual Volume Increment of Beech Seed Trees | $m^3$/ha/year | AAVI |
| 13 | Average Basal Area of Beech Seed Trees | $m^2$/ha | ABA |
| 14 | Stand Canopy closure | --- | SC |
| 15 | Mixture Ratio of Beech Seed Trees | % | MR |
| 16 | Light Density | % | LI |
| 17 | Average Crown Projection Area of Beech Seed Trees in Experimental Plot | $m^2$ | ATPA |
| 18 | Average Crown Width of Beech Seed Trees in Experimental Plot | m | ATW |
| 19 | Absolute Soil Depth | cm | ASD |
| 20 | Physiological Soil Depth | cm | PSD |
| 21 | Rootlet Status | --- | RS |
| 22 | Structure Type | --- | SUT |
| 23 | Soil Type | --- | ST |
| 24 | Soil Reaction in the Upper Soil Layer (pH) | --- | SR |
| 25 | Amount of Organic Substance in the Upper Soil Layer (Ah) | % | AOS |
| 26 | Amount of Nitrogen in the Upper Soil Layer (Ah) | % | AZOTE |
| 27 | Amount of Phosphor in the Upper Soil Layer (Ah) | ppm | PHOSPHOR |
| 28 | Amount of Potassium in the Upper Soil Layer (Ah) | ppm | POTASSIUM |
| 29 | Saltiness of the Upper Soil Layer (Ah) | dS/m | SALTINESS |
| 30 | Amount of Filled Seeds | item/ha | AFS |
| 31 | Germination Percentage | % | GP |
| 32 | Germination Temperature | $^oC$ | GT |
| 33 | Maturation Time of Seed | day | MTS |
| 34 | Damage by Wild Animals | item/$m^2$ | DWA |
| 35 | 2008 Amount of Precipitation | mm | AP08 |
| 36 | 2008 Average Temperature | ˚C | AT08 |
| 37 | 2008 Thickness of Litter Layer | cm | TLL08 |
| 38 | 2008 Thickness of Rotten Layer | cm | TRL08 |
| 39 | 2008 Thickness of Humus Layer | cm | THL08 |
| 40 | 2008 Density of Weed | % | DW08 |
| 41 | 2009 Amount of Precipitation | mm | AP09 |
| 42 | 2009 Average Temperature | ˚C | AT09 |
| 43 | 2009 Thickness of Litter Layer | cm | TLL09 |
| 44 | 2009 Thickness of Moder (decayed) Layer | cm | TRL09 |
| 45 | 2009 Thickness of Humus Layer | cm | THL09 |
| 46 | 2009 Density of Weed Growth | % | DW09 |
| 47 | 2010 Amount of Precipitation | mm | AP10 |
| 48 | 2010 Average Temperature | ˚C | AT10 |
| 49 | 2010 Thickness of Litter Layer | cm | TLL10 |
| 50 | 2010 Thickness of Moder (decayed) Layer | cm | TRL10 |
| 51 | 2010 Thickness of Humus Layer | cm | THL10 |
| 52 | 2010 Density of Weed Growth | % | DW10 |

The number of beech seedlings per square meter in 2010 has been taken as dependent variable and factors affecting this have been examined. In factor analysis, 8 common, basic factors have been identified by using *Principal Component Analysis* and *Kaiser* Criterion (*Table 2*).

*Table 2. Total variance explained for the first 12 components*

| Components | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|
| | Total | % of Variance | Cumulative Variance (%) | Total | % of Variance | Cumulative Variance (%) |
| 1 | 28.145 | 34.312 | 34.312 | 15.935 | 31.853 | **31.85** |
| 2 | 7.546 | 16.242 | 50.554 | 7.683 | 20.431 | **52.28** |
| 3 | 6.845 | 11.773 | 62.327 | 6.815 | 12.752 | 65.03 |
| 4 | 3.615 | 7.665 | 69.992 | 5.554 | 10.026 | 75.06 |
| 5 | 2.715 | 5.337 | 75.329 | 4.825 | 8.448 | 83.51 |
| 6 | 2.413 | 3.226 | 78.555 | 3.673 | 5.761 | 89.27 |
| 7 | 2.105 | 2.475 | 81.030 | 2.849 | 3.275 | 92.55 |
| 8 | 1.187 | 1.245 | 82.275 | 2.776 | 1.842 | **94.39** |
| 9 | 1.170 | 1.110 | 83.305 | | | |
| 10 | 1.163 | 1.006 | 84.311 | | | |
| 11 | 1.152 | 1.002 | 85.313 | | | |
| 12 | 0.996 | 0.785 | 86.098 | | | |

**Extraction Method:** Principal Component Analysis

As shown in *Table 2*, first 8 factors with an eigenvalue above 1 are identified. The first factor explains 31.85% of total variance. First and second factors together explain 52.28%. The 8 common, basic factors explain 94.39% of total variance.

In order to facilitate the identification and interpretation the factor, rotated factor matrix has been calculated *(Table 3)*. Factor loads smaller than 0.5 are not included in this chart for the sake of clarity.

*Table 3. Rotated component matrix (if more than five components, only the first five shown)*

| Variables | Factors | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| AFS | 0.999 | | | | | | | |
| GP | 0.998 | | | | | | | |
| GT | 0.996 | | | | | | | |
| MTS | 0.995 | | | | | | | |
| DWA | -0.993 | | | | | | | |
| TLL10 | | 0.994 | | | | | | |
| TRL10 | | 0.992 | | | | | | |
| THL10 | | 0.988 | | | | | | |
| DW10 | | -0.985 | | | | | | |
| TLL09 | | 0.982 | | | | | | |
| AD | | | 0.991 | | | | | |
| AH | | | 0.990 | | | | | |
| ABST | | | 0.988 | | | | | |
| NBST | | | 0.983 | | | | | |
| AV | | | 0.980 | | | | | |
| SC | | | | 0.989 | | | | |
| MR | | | | 0.985 | | | | |
| LI | | | | 0.980 | | | | |
| ATPA | | | | | 0.986 | | | |
| ATW | | | | | 0.984 | | | |
| ATF | | | | | 0.979 | | | |
| ABF | | | | | 0.975 | | | |
| AOS | | | | | | 0.981 | | |
| AZOTE | | | | | | 0.980 | | |
| PHOSPHOR | | | | | | 0.977 | | |
| POTASSIUM | | | | | | 0.973 | | |
| ASD | | | | | | 0.970 | | |
| SR | | | | | | | 0.972 | |
| SALTINESS | | | | | | | -0.967 | |
| HSEA | | | | | | | | 0.970 |
| AEA | | | | | | | | -0.965 |
| EEA | | | | | | | | 0.953 |
| SEA | | | | | | | | -0.932 |

**Extraction Method:** Principal Component Analysis
**Rotation Method:** Varimax with Kaiser Normalization

As seen in the rotated factor matrix, correlations among 52 variables are represented by 8 common factors. In every factor, the highest correlated variable appears in the first place. Thus, the first variable of the first factor is the amount of filled seeds, the first variable of the second factor is thickness of litter cover in the year 2010; and so on – see *Table 3* and *4*. This way the most influential factors for the success of natural regeneration of oriental beech in the Sökü experiment have been identified. The factors are listed in *Table 4* with their variance contributions.

*Table 4. List of factors most influential in the regeneration success*

| The Name of Factor | Variance contribution (%) |
|---|---|
| 1. Amount of Filled Seeds | 31.85 |
| 2. Soil Cover | 20.43 |
| 3. Growth Status of Seed Trees | 12.75 |
| 4. Stand Canopy closure | 10.03 |
| 5. Average Crown Projection Area of Beech Seed Trees | 8.45 |
| 6. Amount of Organic Substance in the Upper Soil Layer | 5.76 |
| 7. Soil Reaction in the Upper Soil Layer | 3.28 |
| 8. Hillside Status | 1.84 |
| Total | 94.39 |

Multivariate regression analysis was performed to examine the effects of the most important nine factors (independent variables) that were identified by the factor analysis on the beech seedlings' number. In the multiple regression analysis, the beech seedlings' number per square meter in the year 2010 (SN.10) was used as dependent variable. Results obtained by Enter Method are given in *Table 5*.

*Table 5. The results of multivariate regression analysis*

| Model | Standardized Coefficient | Standard Error | F | $R^2$ |
|---|---|---|---|---|
| (Constant) | 0.782 | 0.651 | | |
| AFS | 0.936** | 0.000 | | |
| TLL10 | 0.00453 | 0.004 | | |
| AD | –0.00158 | 0.003 | | |
| SC | 0.133** | 0.000 | 7.895*** | 0.92 |
| ATPA | 0.245** | 0.000 | | |
| AOS | 0.237** | 0.000 | | |
| SR | 0.00546 | 0.007 | | |
| HSEA | –0.00047 | 0.005 | | |

**Dependent variable**: SN.10 (beech seedling number per square meter in the year 2010)
(******): P=0.01 significance level
(*******): P=0.001 significance level

According to regression analysis result, 92% of the regeneration success in the research area stems from these aforementioned 8 factors. But the most important among them are AFS, SC, ATPA and AOS. These four factors affect seedling number at 99% significance level in the positive direction. According to these results, the multivariate regression model can be written as

$$\boldsymbol{Y}_{(SN10)} = 0.782 + 0.936\boldsymbol{X}_{(AFS)} + 0.00453\boldsymbol{X}_{(TLL10)} - 0.00158\boldsymbol{X}_{(AD)} + 0.133\boldsymbol{X}_{(SC)} + 0.245\boldsymbol{X}_{(ATPA)} + 0.237\boldsymbol{X}_{(AOS)} + 0.00546\boldsymbol{X}_{(SR)} - 0.00047\boldsymbol{X}_{(HSEA)}$$

## 4 DISCUSSION

Out of the 8 factors that have been obtained as a result of factor analysis, amount of filled seeds takes the first place. There is also an apparent relation between amount of filled seeds and germination percentage of beech seeds. Saatçioğlu (1969), Szwagrzyk et al. (2001) and Çepel (1995) have also found that out of many factors affecting the success of regeneration, the amount of filled seed and germination percentage have evident importances.

The second factor determined by factor analysis is soil cover *(Table 3* and *Table 4)*. The soil cover includes weed and litter cover. As the density of weed cover and thickness of litter cover in the regeneration area increases, the number and growth of oriental beech seedlings decreases. It is proven that intense weed cover, particularly pontic rhododenron (*Rhododendron ponticum* L.) cover is an important problem as stated in chapter 3.1 already. Intense weed control and soil cultivation have especially positive effects on seedling development (Saatçioğlu 1970, Suner 1978).

The growth status of seed trees is the third factor having an effect on the success of regeneration *(Table 4)*. Trees in the stand should be in the age of maturity in order that regeneration practices can be carried out in a stand (Saatçioğlu 1979, Atay 1987). Trees that haven't reached the full status of maturity yet, cannot yield enough seed, especially as they haven't completed crown growth.

The next factor is the stand canopy closure *(Table 3 and Table 4)*. There is an important relation between stand canopy closure and light density. Light density is effective on germination, site condition and soil cover (weed and litter cover) (Çepel 1995). It is stated by many researchers that oriental beech, growing up slowly in the seedling period, needs protective upper cover until it gains its biological independence (Saatçioğlu 1969, Suner 1978, Atay 1987).

The fifth factor affecting the success of natural regeneration practice in oriental beech is average crown projection area of beech seed trees *(Table 4)*. Trees that haven't reached the age of maturity yet, cannot hold enough seed as they haven't completed especially crown development. On the other hand, as age advances, beech spreads its crown and crown decay starts in the upper parts. Because of the decay in the crown of oriental beech trees, capacity of seed holding decreases and this affects the number of seedlings negatively.

The amount of organic substance in the upper soil layer *(Table 3, 4)* is the sixth factor. Seedlings of beech benefit from the water and nutrients in the soil mostly in terms of root growth. In European beech silviculture it is known that the species develops best in soils which are rich in organic substance (Kerr 1995).

The seventh factor is soil reaction in the upper soil layer *(Table 4)*. There is a positive relation between amount of soil reaction in the upper soil layer and number of oriental beech seedlings *(Table 3)*. In a research carried out by Akgül and Aksoy (1976) in the Research Forest of Bolu-Şerif Yüksel, they confirmed that there is an important relation between root growth, soil reaction and the amount of organic substance.

Hillside status is the eighth factor affecting the success of natural regeneration practice in oriental beech in the research area *(Table 3, 4)*. Hillside status is an important physiographic variable influencing local habitat conditions. Depending on the changes in hillside status, microclimatic and edaphic conditions also change dramatically (Çepel 1995). Beech reaches its optimum development at middle and sub hillside (Peters 1992). Outside these conditions the density of beech stand decreases, diameter and height growth decline, crown growth weakens and crown form deteriorates. These changes of the beech trees cause the deterioration of stand structure and fertility.

## 5 CONCLUSIONS

In order to increase the success of beech natural regeneration in the practice the following suggestions are formulated:

- Good seed years should be identified correctly in the stands planned for regeneration.
- The presence of seed trees in sufficient quantity and homogeneity is an important precondition. Regeneration practices should be applied only in stands which are in the age of maturity.
- Before acorn fall in the regeneration area, litter and weed cover, especially pontic rhododenron should be cleared, to provide better conditions for rooting. It should be taken care of mixing litter cover with mineral soil by intensive soil cultivation. After beech seedlings appeared, the necessary tending and weeding should be applied in sufficient frequency and in time.

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