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Full Length Research Paper

The use of growth models in ınvestigatıng oriental beech (*Fagus orientalis* Lipsky.) natural juvenitilies growth performance

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In this study, Richards, Gompertz and Weibull Growth Models were applied to the results of root collar diameter measurement carried out between the years 2004 - 2010 in beech natural juvenilities situated within 10 experimental areas sized 25 m x 40 m in Bartın-Yenihan Forest Range District 70b division in the size of 12.0 ha oriental beech natural regeneration areas so as to define the best growth model to estimate the juvenility development. According to attained results, it was ascertained that the best model to be used and to be able to estimate the oriental beech juvenility height and root collar diameter development -with the ecological conditions of Yenihan district as well- is Richards Growth Model by 95.31 and 0.95 model coefficient of activity, respectively.

Keywords: Oriental beech, growth model, height, root collar diameter, natural regeneration.

INTRODUCTION

Turkey -owing to different development conditions turned up depending on many various climate and physiographic conditions- has pure and mixed natural forest resources whose economic value is high in terms of both tree kind and stand establishments. According 2006 data our countries total forest area is 21.188.747 hectares. This figure comprises a great part of nation's area- some like 27.2%. In terms of its qualifications, forest resources that we have are productive high forests and productive coppice forests in 50% (10.621.221 ha), and are unproductive high forests and unproductive coppice forests in 50% (10.567.526 ha) (Anon, 2006). As it is undestood from these figures, the great part of our national forests' natural structure are distorded and unproductivity because of various biotic and abiotic factors such as over-exploitations, wrong technical interventions, fires, snow and storm damages. Depending on this decrease of productivity in natural forest resources, the product amount from this resources has decreased year by year.

According to recent data, 15 - 16 million m^3 products can be taken from our national forests. This rate suntends approximately to a 0.750 - 0.800 m^3/ha increase per year. This amount is rather low when compared to countries like Romania (2.6 m^3/ha), Greece (2.1 m^3/ha) and old Yugoslavia (2.7 m^3/ha) (Ürgenç, 1998). Upscaling of this rate and increase of forestry sector's proportion in national income depending on this will only be possible with amendment -in terms of quality and quantity- of natural forest resources whose natural structures are distorted by various reasons -as a result, they have been unproductivity- by successful regeneration studies (natural or artificial regeneration) and forestations to be carried out in infertile forest areas to make them fertile. The fact that Turkish forests, depending on different growing ecological conditions, have quite variations in terms of kind diversity and stand establishments are directly at work upon determining techniques that will be applied in regeneration and maintenance studies and success of these studies- it is because there are so many factors directly and indirectly affecting especially natural regeneration studies' success (Pamay, 1962; Ata, 1975; Çepel et al., 1977; Bozkuş, 1990; Çalışkan, 1991).

Oriental beech (*Fagus orientalis* Lipsky.) comes in the first place of spreading kinds naturally in Turkish forests which are quite rich in terms of kind diversity with the

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effect of different growing site conditions. Oriental beech (*F. orientalis* Lipsky.) is the 4th most spreading kind with 1.7 million ha spreading area. Beech forests total fortune is 263.772.103 m^3 and total yearly increment is 6130147 m^3. Oriental beech's vertical spreading is between 10 and 800 m in Balkans. Yet, in our country, it reaches about 1500 - 1700 m in Blacksea inner-valleys and up to 2000 m in Aegean mountains. The only kind of beech in Turkey, Oriental beech, gets interfered with the kinds of Nordmann fir (*Abies nordmanniana* Stev.), Uludağ fir (*Abies bornmülleriana* Mattf.), Kazdagı fir (*Abies equi-trojani* Spach.), Scotch pine (*Pinus sylvestris* L.), Black pine (*Pinus nigra* Arnold. subsp. *pallasiana* (Lamb.) Holmboe) and Oriental spruce (*Picea orientalis* L.) near its upper spreading points as well as it makes pure wide forests linked to each other (Saatçioğlu, 1969; Atay, 1987; Atalay, 1992).

The obcejtıves of research

Generally, considered within operational researches, growth model is an intensely-used technique to objectively demonstrate the growth performance of the kinds in different ecological conditions, to indicate future-proof growth projections and to determine alternative techniques in silvicultural applications. Operational research techniques provide important benefits in planning intense-labour forestry activities in open area circumstances and in making forest resources run effectively. On the other hand, operational analyses called resolving techniques in activities of forestry-goods-industry are quite important in terms of most effectively supplying forest goods neccessity that society highly demands (Başkent, 2004). In this study that is carried out with Uniform Shelterwood Method (USM) in 70b division of Yenihan Forest Range District affiliated to Bartın Directorate of Forest Enterprises, the growth performance of juvenilities taken from 10 experimental areas sized 25 m x 40 m in 12.0 ha sized beech natural regeneration area has been traced for 7 years. For this purpose, the most important indicators of growth in juvenilities, height and root collar diameter measurements, are fulfilled every year. This study, by utilizing the results of height and root collar diameter measurements of beech natural juvenilities between 2004 - 2010, produces practical informations to determine the best growth model that can be used to explain this kind's of growth performance and to provide correct predictions about beech juvenilities' growth in similiar ecological conditions to those the study has been taken place for Forest Engineers who are assigned in this application. For this aim, many experiments especially growth models use to explain forest trees' development are examined and evaluated. For instance, Zhang (1997), has examined changes in stem diameter and height growth in 10 different oak kinds using six non-linear growth functions (Gompertz, Korf-Landqvist, Richards, Weibull and Schnute). While all models' coefficient of specification is 0.98, error squares medium has varied and has become 4.11, 4.04, 4.06, 4.02, 4.01 and 4.02, respectively. Weibul models' parameter rates have been a:50.20, b:0.0118, c:1.1533 and d:1.2310 while indicating the best definition. Gompertz function has been detected to predict less successfully with regard to the others.

Fekeduleng et al. (1999) have tried to specify the model describing forest trees' development in Norway using Negative ussel, Monomoleküler, Mitcherlich, Gompertz, Lojistik, Chapman-Richards, Von Bertalanffy, Weibull and Richards models. When evaluated generally, Weibull model is designated to be the best model to describe tree development. While parameter values of this model are a:27.2229, b:26.2435, b:0.0051 and d:1.3263, coefficient of specification is 0.98, error squares medium occurs as 0.13. Logistic model, however, has become the least describing model with 0.86 coefficient of specification, 0.18 error squares medium and 22.8643, 6.7094 and 0.0590 parameter values.

Liao et al. (2003) have tried to describe South America pine kinds' tree diameter and height growth using Mitscherlich, Lojistik, Gompertz and Korf growing functions. They compared the models by using coefficient of specification and error squares medium. According to this, while parameter values of models have been a: 19.0287, 18.5876, 19.0287 and 30.1982, b: 0.1125, 0.2349, 0.1606 and 3.2055, respectively, c parameter has been 2.1105 in logistic, 0.9749 in Gompertzte and 1.6921 in Korf. Coefficient of specification and error squares medium values according to models have indicated Korf model to be best with 96.77, 96.97, 99.14 and 99.89; 1.1704, 0.9470, 0.2700 and 0.0351.

Colbert et al. (2004) have tried to define some characters developments such as forest trees height growth and diameter development by using Chapman-Richards, Richards, Von Bertalanffy and Weibull sigmoidal growth models. In terms of examined features, Chapman-Richards model has been stated to give the best result, Von Bertalanffy model to follow it and Richards model to be the weakest model to be described. While these models are compared, error squares medium size has been taken essential. According to this, while Chapman-Richards model's error squares medium has been 0.0000520 and parameters have been a:0.6, b:0.15, c:0.015 and d:0.15; Richard model's error squares medium has been 0.0000938 and parameters have been a: 0.6, b: 0.01, c: 0.03 and d: 0.2.

Fan and Gertner (2004) have studied on white pine height growth in their studies in which they have analyzed Richards and Morgan-Mercer-Flodin (MMF) growth models parameter. According to this, they have stated that while MMF model parameters show normal range and describe better, Richards model does not disperse normally, show a Gamma range and does not describe enough. While parameter values in MMF model have

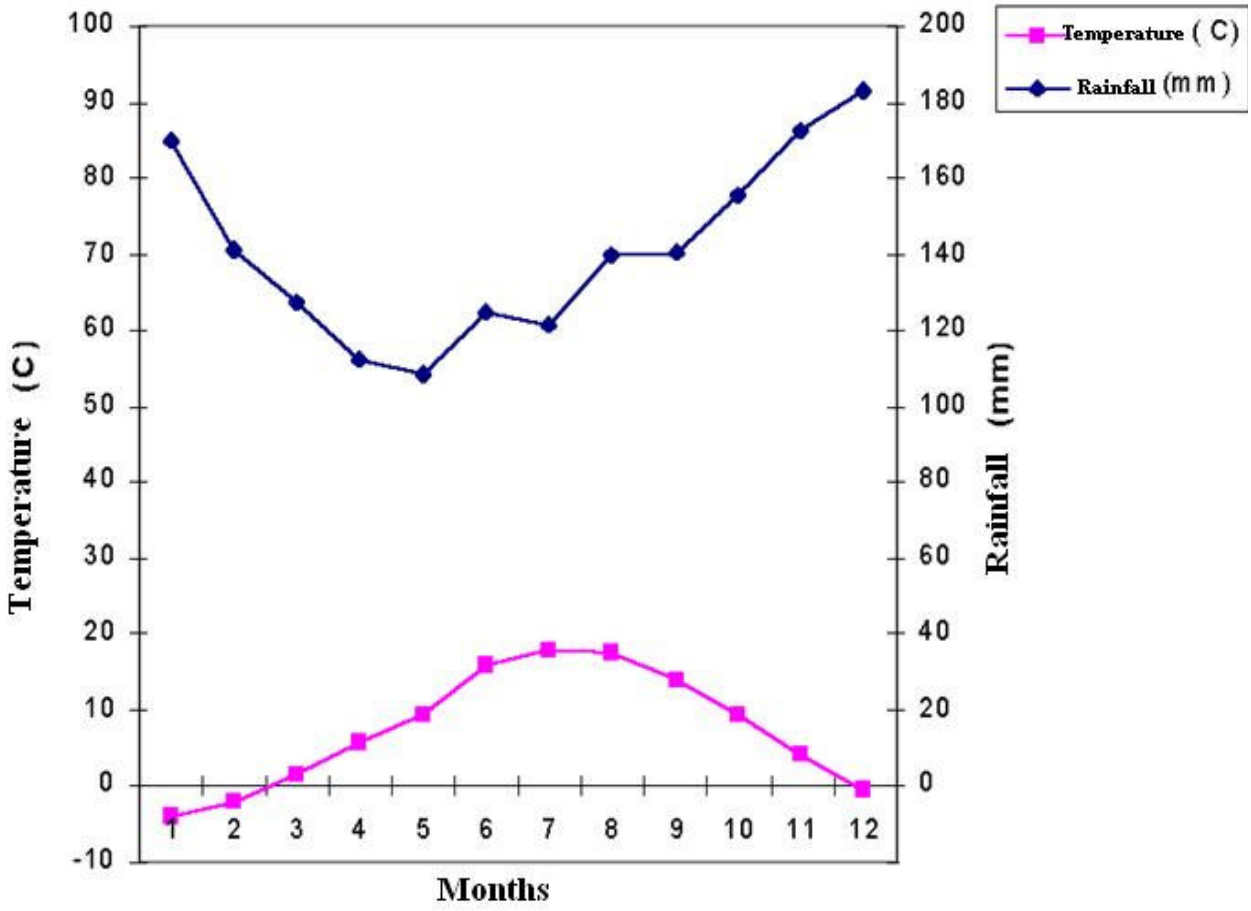

Figure 1. Climate diagram according to Walter method.

been a: 35, b: 0.5, c: 400 and d: 1.8, they have been detected to be a: 40, b: 0.035, c: 0.3 and d: 0.308 in Richards model.

MATERIALS AND METHODS

Materials

Introduction of Yenihan forest range district

Yenihan Forest Range District affiliated to Bartın Directorate of Forest Enterprise is in the sections E28-c3, E29-d4, F28-b2 and F29-a1 of 1/25.000 scaled Zonguldak topographical map. According to this, Yenihan vicinity is between 41˚ 31'56" - 41˚ 29' 47"east meridians and 32˚ 32'36"- 32˚ 01' 00" North latitudes. Horizontal distance of planned unit to the sea is 35 km. Average altitude of Yenihan Forest Enterprise Chieftaincy having generally an undulating ground is 515 m. Study area is in the northwest euxin sub forest zone of euxin forest zone (Mayer and Aksoy, 1998). According to the data obtained as a result of inventory studies in 2000, there are 5183.7 ha forest area in total in Yenihan planned unit. 63.6% (3297.8 ha) of this forest area is normal, 36.4% (1885.9 ha) of its are distorted forest (Anon, 2001).

According to Turkey macroclimate types classification, Yenihan vicinity is under the influence of West Blacksea subclimate type (IIc) (Saatçioğlu, 1969; Özyuvaci, 1999). There is no meteorological station within the study area. So as to have general information about the climate of a vicinity whose approximate altitude is known but there is no meteorological station in it, Çepel (1995) and Özyuvaci (1999) suggest that temperature and precipitation values from a meteorological station whose approximate altitude is known should be interpoled by using Schreiber and Lapse-Rate formulas. Therefore, long (51 years) approximate data from the nearest meteorological station in 32 m altitude -Bartın Meteorological Station- are utilized to draw climate diagram of study area according to Walter method. According to these rates, Yenihan vicinity's annual approximate temperature is 8.2℃ with the lowest month January (-4.2 ℃), and the highest months July (17,7℃) and August (17,4℃). Besides, the vegetation period in the area is 4 months (June-September). Study area's climate diagram designed by Walter method is as shown in Figure 1.

When climate diagram in Form 1 is examined, precipitation and temperature curves do not intersect each other. According to this, there is no drought circuit as there is precipitation in every season. Geological structure in Yenihan vicinity formed in cretaceous era (Mesozoic) of II Era. Because of this, bedrock in the region is in sedimentary structure. There are calcerous, clay, marl, schist, conglomerate and flysch formations especially in the step and slopped parts of region. There are sandstone formations in smooth and less slopped parts (MTA, 2002). Besides, in development and detail silviculture plan, it is stated that general soil structure in planned unit belonging to Yenihan Forest Range District is in the texture of less stony, mediocre depth, alkaline, sandy mud and sandy clayish (Anon, 2001).

In division 70b of pure beech stand which research has been carried out in 2003, seed cutting has been performed on account of the fact that it is seed year for beech and total 766 m^3 product has been attained. Stand canopy has been reduced to 0.7 with the seed cutting. As a result of examinations and observations carried out in beech juvenilities, it is determined that light necessity of juvenilities has been increased and canopy has been reduced to 0.5 with a light cutting in 2006 and total 372 m^3 last revenue product has been taken.

Methods

Features of experimental areas

In a scientific research, determination of sample size has great importance in terms of reliability of research results. In our country various researchers studying on the similiar subjects to this research have taken the different sample sizes in order to determine stand foundations and biology of juvenilities essential. For instance, Pamay (1962) has studied on the experimental areas varying between 4 x 16 , 10 x 50 and 20 x 100 m according to the situation required to be determined in stand. Ata (1975), Aksoy (1978), Ozalp (1989), have studied generally on the experimental areas in size of 10 x 50 m. Suner (1978), in research Suner did in the stands of pure oriental beech in the zone of Duzce, Cide and Akkus, took experimental areas in the size of 90 x 90 m. In this research, too, it has been deemed suitable that experimental areas are to be taken in the size of 25 x 40 m (1000 m^2) considering the aim of research, time, working facilities and situation of land. Form of the experimental areas has importance in terms of its boundaries' being applied easily and healtily to the land. Experimental areas' having been taken in the form of circle, is a suitable geometric figure in terms of diminishing the number of trees on the edges and cutting mistakes to the lowest. But, that areas in the size of 0.1 ha -or greater circle- are hard to be formed to the ground because of the slope, is not used because it increases the number of suspicious tree on the edge. In this case, it is suggested to use experimental areas in the shape of square or rectangle (Kalipsiz, 1993; Atici, 1998; Carus, 1998). In the research, it is decided that experimental areas should be taken in the shape of rectangle considering the matters such as tally of beech juvenilities and measurements of detail. During the planning of research, determination of the number of sample to be taken is very important. Because if redundant sample is taken, time and oppurtunities will be skidded. On the other hand, if inadequate sample is taken, socio-parameters will be forecasted only in a vast distance. In the frames of these matters, taking 10 testing areas in the size of 25 x 40 m in the partition of 70b out of 12.0 ha sized the natural regeneration area is considered enough to obtain necessary data.

Measurements and evaluations carried out in experimental areas

Height of juvenilities is an important indicator in terms of determining the situation of growth especially in the first years. With this aim in the research, height of the beech juvenilities has been measured as in the same individuals for 7 years (2004 - 2010) in the experimental areas. Root collar diameter is another variable used in determining the growth in the juvenilities according to years. Root collar diameter is a criterion having a great importance in terms of determining whether newly-germinated seedlings improve their root systems or not. In fact, as a result of research carried out in some kinds, it appeared that there is an important relation between the root collar diameter and oppurtunities of utilization of plants from the water and nutrition elements in the soil (Tosun, 1992; Chapek, 1996; Genc, 2004).

Application of growth models

Raw data used in this study have been obtained as a result of detail measurements applied in the experimental areas which are taken according to the incidental sampling system throughout 7 years. In measurements carried out in the sampling areas, height (cm) and root collar diameter values of juvenilities have been determined. By using these data, predictions of growth curve below have been made and these models have been compared. In study, these mathematical models which are used intensely in predicting the growth of trees have been used by many researchers:

1. Richards Growth Model: $Y = a(1 \pm be^{-ct})^d$

2. Gompertz Growth Model: $Y = ae^{-be^{-ct}}$

3. Weibull Growth Model: $Y = a - be^{-ct^d}$

Paremeters of the models can be explained thus;

(a) It is the asymptote value of size.
(b) It means the size values in the period when trees begin to grow up.
(c) It means explicit growth rate.
(d) It means instant rate of growth in the inflection point.

Criterions of Model Comparison are thus;

(1) Coefficient of Specification (R^2):

$$R^2 = 1 - \frac{TES}{GTS}$$

shown as this. While *TES* shows the total of error squares; *GTS* shows the total of general squares. (Başkent, 2004; Düzgunes et al., 1987). Coefficient of specification varies between 0 and 1. As it approaches to 1, harmony of the model increases.

(2) Mean of Error Squares (MES):

$$MES = \frac{TES}{n}$$

shown as this. While *TES* shows the total of error squares; n means the number of observation. (Başkent, 2004; Düzgunes et al., 1987). MES model closest to zero is preferred.

(3) Model Efficiency (ME):

$$ME = 1 - \frac{\sum_{i=1}^{i=n}(P_i - O_i)^2}{\sum_{i=1}^{i=n}(O_i - \bar{O})^2}$$

In case value of Model efficiency is above 90%, it is accepted as efficient (Baskent, 2004; Mohanty and Painuli, 2004). Datas have been analysed in the Statistical 6.0 pack program and evaluated.

RESULTS AND DISCUSSION

In this study, graphic of the values predicted according to

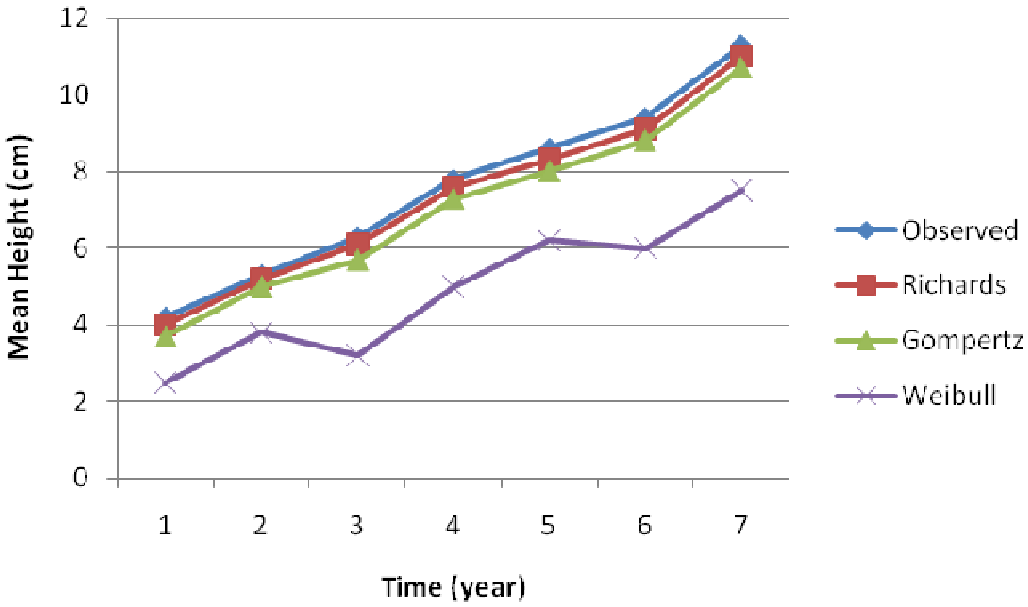

Figure 2. Curves belonging to the values related to height growth of Oriental beech juvenilities observed and values predicted according to the models.

Table 1. Efficiency status of models in height growth of juvenilities according to the comparison criterions.

Models	Parameters	R^2	MES	ME
Richards	a; 4.03569 b; 0.35662 c; 1.15809 d; 0.1000	97.67	0.7570	95.31
Gompertz	a; 4.77740 b;-0.51987 c; 0.07588	96.19	1.2297	91.64
Weibull	a; 10.01820 b; 0.00609 c; -0.14128 d; 109.3700	45.44	13.0797	58.49

the models and height growth of beech juvenitilies is shown in the Figure 2. When Figure 2 is examined it is seen that while the worst approach is in the model of Weibull, the best approach is in the model of Richards. Although, Gompertz growth curve gives near values to the Richards model, it has a value below this model. Though Weibull model is used successfully in describing the height growth of juvenilities, it has not shown a well description in this study. Status of models according to the comparison criterion are shown in Table 1. When Table 1 is examined, as Richard model is the highest with 97.67 R^2 value, Gompertz model followed this with the value of R^2 = 96.19. Despite that Weibull model has very low value of R^2 with 45.44. Average error squares values are arranged as coefficient of specification. When we look at the efficiency of the models, it is seen that Richards and Gompertz models are efficient, Weibull model is not efficient. In a research, too, carried out in Norway natural forests by Fekeduleng et al. (1999), they determined that beside Richards and Gompertz models' are not the most efficient models, they have important coefficient of specification in determining the growth.

Graphic belonging to the estimated values according to the models and values observed related to root collar

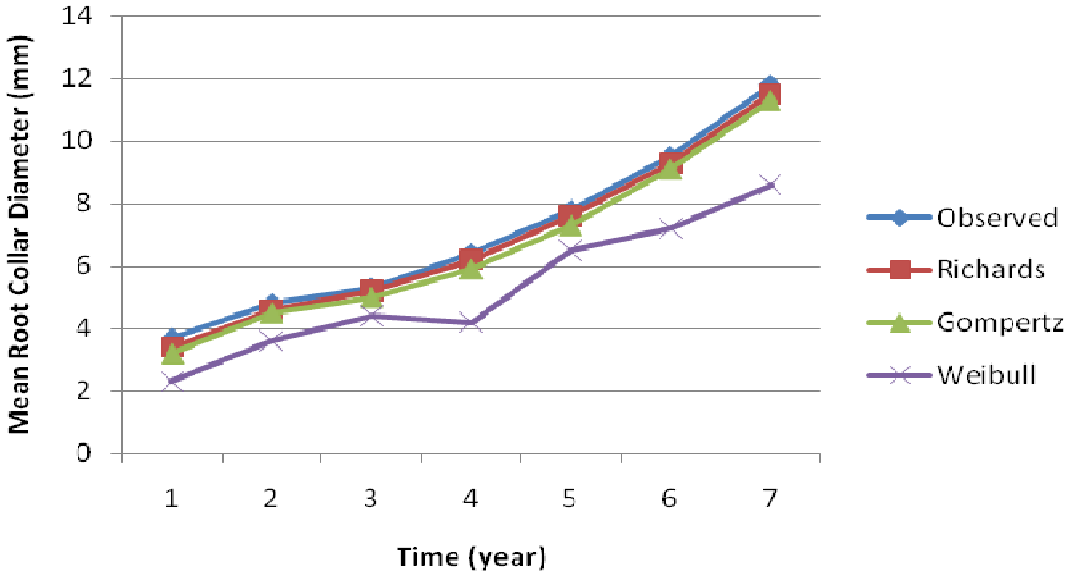

Figure 3. Curves belonging to the values related to root collar diameter of oriental beech juvenilities observed and values predicted according to the models

Tablo 2. Efficiency status of models in root collar diameter of juvenilities according to the comparison criterions.

Models	Parameters	R^2	MES	ME
Richards	a; 3.9129 b; 0.0007 c; 0.5135 d; 0.0329	97.96	0.6672	0.95
Gompertz	a; 4.6582 b; 0.9748 c; 2.0000	96.42	1.1603	0.91
Weibull	a; 9.7295 b; 1.9888 c; 0.2714 d; 1.0000	31.76	14.8569	0.47

diameter growth of beech juvenilities are shown in Figure 3. When Figure 3 is examined, it is seen that Richards and Gompertz models show a curve near to the values observed whereas Weibull model makes quite an unsuccessful estimate. Status of models according to the comparison criterions is shown in Table 2. According to Table 2, similiar results to height growth of height models have been obtained. Whereas, coefficient of specification is the highest in Richards model again, Gompertz model followed this. Weibull model has again the lowest coefficient of specification. While, MES values of Richards and Gompertz models are low in terms of error squares average and model efficiency, value of Weibull is high and it has been determined that this model has no model efficiency. In research carried out by Fan and Fertner (2004) it is determined that Chapman-Richard model explains the diameter growth of trees best. On the other hand, in other research carried out by Colbert et al. (2004), it has been determined that Morgen-Mercer-Flodin (MMF) model explains the diameter growth of trees best.

According to the results of this research carried out by using the values obtained from the measurements of height and root collar diameter on juvenilities in 2004 - 2010 in the oriental beech natural regeneration area 70b division of Yenihan Forest Range District, it arised that beech juvenilities under the dominant ecological circumstances in the research area shows similiar

reactions to each other in terms of heigth and root collar diameter improvement. Various mathematical growth models applied to the values of root collar diameter growth and heigth growth obtained with the results of measurement at the end of the vegetation season for 7 years made an estimate in the level of various determination. According to this estimated results made by the different mathematical models, it is determined that Richards is the model that shows the best prediction for height and root collar diameter growths of oriental beech juvenilities in the research area. Within this context, in the future in Bartın- Yenihan district and areas having the similiar habitat conditions, it will be quite beneficial for Richards model to be used by the pragmatists in predicting the height and root collar diameter growth of natural juvenilities related to oriental beech. Thus, error rate will be decreased as possible in carrying out the other maintenance techniques, especially stages of light and removal cuttings, in the right time.

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