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Growth models in investigating oriental beech (*Fagus orientalis* Lipsky.) juvenilities growth performance in the Western Black Sea in Turkey (Devrek-Akçasu Case Study)

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Abstract

In this study, Richards, Gompertz, Weibull and Logistic Growth Models are applied to the results of root collar diameter measurement carried out between the years 2001-2010 in beech natural juvenilities situated within 20 experimental areas, sized 25x40m, in Devrek-Akçasu Forest Range District 56c division, in the size of 16.0 ha oriental beech natural regeneration areas, so as to define the best growth model to estimate the juvenility growth. According to results, it is ascertained that the best model to be used to estimate the oriental beech juvenility height and root collar diameter development - with the ecological conditions of Akçasu district as well- is Gompertz Growth Model by 99.48 and 0.97 of model efficiency respectively.

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

Introduction

Forests, important part of natural balance on earth, are one of the most important natural resource of the world because of their economic and ecological benefits. But, with the influence of excessive utilizations and other natural factors (biotic and abiotic factors), natural forest resources have been decreased dramatically all over the world. In our century, decline of natural forest resources is going on, depending on increasing population and industrialization. Especially, as a result of excessive utilizations of forest resources with the aim of providing growth of demand towards raw wood, 180 million hectares of natural forests and plantation forests in the world during 1980-1985 have been vanished. This rate reached 200 million hectares today. [13]. Demolition of forest resources - providing allround ecological and economic benefits to the community life - for various reasons (excessive utilization, fires, tip- ups which are done for acquisition of agriculture and settlement, acid rains, storm and snow harms, etc..) caused greater environment problems on earth. Erosion, disasters of flood and avalanche, air pollution, negative climate changes, decline of biological and genetical variety head the environment problems [9].

Turkey -owing to different development conditions, 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 to 2006 data, Turkey forest area is 21.188.747 hectares. This figure comprises a great part of national 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% (10.621.221ha), and are unproductive high forests and unproductive coppice forests in 50% (10.567.526 ha) [3]. As it is undestood from these data, the great part of our forests natural structure is distorded and unproductive because of various biotic and abiotic factors such as over-exploitations, wrong technical interventions, fires and other damages. Depending on this decrease of productivity in natural forest resources, the product amount from these resources has decreased year by

year. 15-16 million m^3 yields can be taken from our national forests. This rates approximately a 0.750-0.800 m^3/ha increases per year. This amount is rather low when compared to countries like Romania (2.6m^3/ha), Greece (2.1m^3/ha) and old Yugoslavia (2.7m^3/ha) [23]. Forestry sector and its contribution to Turkey share of the national economy to increase, unproductive forest areas must be streamlined. For this purpose, natural and artificial regeneration of successful applications should be made.

Oriental beech (*Fagus orientalis* Lipsky.) comes in the first place of naturally spreading kinds in Turkish forests which are quite rich in terms of kind diversity with the effect of different growing site conditions. Oriental beech is the 4th most spreading kind with 1.7 million ha spreading area. Oriental beech forests total growing stock is 263.772.103m^3 and total yearly increment is 6130147 m^3. Oriental beech vertical spreading is between 10 and 800 m in Balkans. Yet, in our country, it reaches about 1500-1700 m in Black Sea 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.), Kazdağı fir (*Abies equi-trojani* Spach.), Scotch pine (*Pinus sylvestris* L.), Black pine (*Pinus nigra* Arnold) and Oriental spruce (*Picea orientalis* L.) near its upper spreading points, making also pure wide forests linked to each other [5-21].

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 [6]. In this study that is carried out with Uniform Shelterwood Method in 56c division of Akçasu Forest Range District affiliated to Devrek Directorate of Forest Enterprises, the growth performance of juvenilities taken from 20 experimental areas sized 25x40m in 16.0ha sized beech natural regeneration area has been traced for 10 years. For this purpose, the most important indicators of growth in juvenilities, height and root collar diameter measurements, are fulfilled every year. In this study, growth of natural oriental beech juvenilities reveals the status to determine the best growth model was investigated. For this aim, many experiments that especially use growth models to explain forest trees and agriculture plants growth were examined and evaluated.

Zhang [24] 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.

Liao et al. [17] have tried to describe South America pine kinds tree diameter and height growth using Mitscherlich, Lojistik, Gompertz ve 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 ve 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 ve 99.89; 1.1704, 0.9470, 0.2700 and 0.0351.

Colbert et al. [8] 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 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 error squares medium has been 0.0000938 and parameters have been a:0.6, b:0.01, c:0.03 and d:0.2.

Goodness of fit of different growth curves to different characters of rye plant was evaluated by Karadavut and Tozluca [15]. Logistic, Gompertz, Richards and Weibull growth models were tested. Characters measured were total fresh and dry matter upper ground and root fresh and dry weight. Results show that root dry weight was modeled better by fitting Richards's model, while for other characteristics Weibull model was more appropriate.

Karadavut et al. [16] have tried to define Richards, Gaussian and Logistic growth models for describing plants growth. Coefficient of determination (R^2), mean squared error (MSE), model efficiency (ME), mean rational error (MRE), mean squared variation (MSV) and Bias were used as comparison criteria. As results, Richards model described dry matter accumulation of silage and corn seeds better than Gaussian and Logistic growth models. Logistic growth equation described dry matter accumulation of silage and corn seeds worse than others growth.

Material and Method

Material

In this study that was carried out with Uniform Shelterwood Method in 56c division of Akçasu Forest Range District affiliated to Devrek Directorate of Forest Enterprises, the growth performance of juvenilities taken from 20 experimental areas sized 25x40m in 16.0ha sized beech natural regeneration area, has been traced for 10 years. For this purpose, the most important indicators of growth in juvenilities, height and root collar diameter measurements were fulfilled every year. This study, by utilizing the results of height and root collar diameter measurements of beech natural juvenilities between 2001-2010, produces practical information to determine the best growth model that can be used to explain this kind's 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. In the zone of Akçasu taking place in the Western Black Sea Region, effects of Western Black Sea sub-climate (IIc) is the case. According to the results of inventory studies carried out in 2004, total forest area in the region was determined as 7213.2ha; 97% (7007.0ha) of this forest area is normal and 3% (41.4ha) is ruined forest. There is no meteorological station in the zone of Akçasu as in the other research areas in Bartın region. With this purpose, precipitation and temperature values obtained from Devrek meteorological station has been interpoled for Akçasu region whose average altitude is 575m. In the zone of Akçasu each season is rainy, the highest month of average precipitation is November (166.6mm) and the lowest month is May (76.3mm). Average annual temperature is 11.7 °C, the lowest month of average temperature is January (2.0 °C), the highest months are July (20.8 °C) and August (20.7 °C). In addition, vegetation period in the research area is of 6 months. (May – October). General soil structure belonging to the planning unit of Akçasu Forest Range District is declared as in the texture of stony, in mediocre depth, alkaline, clay, clayish mud and sandy clayish mud [2].

In division 56c of pure beech stand which research has been carried out in 2001, seed cutting has been performed on account of the fact that it was seed year for beech and total 978.6 m^3 product has been attained. Stand canopy has been reduced to 0.6-0.7 with the seed cutting. As a result of examinations and observations carried out in beech juvenilities, it was

determined that light necessity of juvenilities has been increased and canopy has been reduced to 0.4-0.3 with an light cutting in 2004 and total 512 m^3 last revenue product has been taken.

Method

Determination of sample size has great importance in terms of reliability of research results in a scientific research. Various researchers studying similar subjects to those of this research have taken different sample sizes in order to determine stand foundations and biology of juvenilities essential. For instance Ata [4], Bozkuş [7], Aksoy [1], Özalp [19] and Pamay [20] have generally studied on the experimental areas in size of 10x50m. Suner [22], in research he did in the stands of pure oriental beech in the zone of Düzce, Cide and Akkuş, took experimental areas in the size of 90x90 m. In this research, it has been deemed suitable that experimental areas are to be taken in the size of 25x40 m (1000m^2), considering the aim of research, time, working facilities and situation of 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 on the areas in the size of 0.1ha -or of a greater circle diameter- this form of the experimental area is hard to be established if the ground is sloppy, therefore is not used because it increases the number of suspicious trees. In this case, it is suggested to use experimental areas in the shape of square or rectangle. [14].

In the present research, it was decided that experimental areas should be taken in the shape of a 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 a 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 20 experimental areas in the size of 25x40m in the division of 56c out of 16.0 ha sized natural regeneration area is considered enough to obtain necessary data.

Height of seedling is an important indicator in terms of determining the situation of growth, especially in the first years. With this aim of the research, height of the beech juvenilities has been measured in the same individuals for 10 years (2001-2010) in the experimental areas. 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 opportunities of utilization of plants from the water and nutrition elements in the soil. [12].

In measurements carried out in the sampling areas, height (cm) and root collar diameter values of seedlings have been determined. By using these data, predictions of growth curve below have been made and these models have been compared. The mathematical models which are intensely used by many researchers in predicting the growth of trees have also been used in the present study:

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

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

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

4. Logistic Growth Model: $$Y = \frac{\alpha}{\left(1 + e^{(\beta - \delta * T)}\right)} \quad (4)$$

Paremeters of the models can be explained as follows:

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;
α- The feature focuses on the asymptotic limit;
β- The initial growth after germination;
δ- The growth rate;
T- Time .

Criterions of Model Comparison are the followings:

Coefficient of Specification (R^2):

$$R^2 = 1 - \frac{TES}{GTS} \tag{5}$$

While *TES* shows the total of error squares; *GTS* shows the total of general squares. [6-10]. Coefficient of s0pecification varies between 0 and 1. As it approaches to 1, harmony of the model increases.

Mean of Error Squares (MES):

$$MES = \frac{TES}{n} \tag{6}$$

While *TES* shows the total of error squares; n means the number of observations. [10]. MES model closest to zero is preferred.

Model Efficiency (ME):

$$ME = 1 - \frac{\sum_{i=1}^{i=n}(P_i - O_i)^2}{\sum_{i=1}^{i=n}(O_i - \bar{O})^2} \tag{7}$$

In the case the value of Model efficiency is above 90%, it is accepted as efficient [18]. Data have been analysed in the Statistica 6.0 pack program and evaluated.

Results and Discussion

Status of models according to the comparison criterion for height growth of oriental beech juvenilities is shown in Table 1. When Table 1 is examined, it reveals that Gompertz model is the highest with 98.56 R^2 value, followed by Richards model with the value of R^2=96.73. Despite that, Weibull and Logistic models have very low value of R^2, of 53.61 and 48.29 respectively. Mean error squares values are arranged as coefficient of specification. When we look at the efficiancy of the models, it is seen that Gompertz and Richards models are efficient, while Weibull and Logistic models are not efficient. In a similar research carried out in Norway natural forests by Fekeduleng et al. [11], it was determined that though Gompertz and Richards models are not the most efficient models, they have important coefficient of specification in determining the growth. Goodness of fit of different growth curves to different characters of rye plant was evaluated by Karadavut and Tozluca [15]. Logistic, Gompertz, Richards and Weibull growth models were tested. Characters measured were total fresh and dry matter, upper ground and root fresh and dry weight. Results show that root dry weight was modeled better by fitting Richards's model, however, for other characters Weibull model is recommended.

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

Models	Parameters	R^2	MES	ME
Gompertz	a: 7.81521±2.34560 b: 0.51987±0.00450 c: 0.07588±0.00647	98.56	0.6234	99.48
Richards	a: 6.09652±3.48567 b: 0.34875±0.00561 c: 1.17426±0.00832 d: 0.10075±0.00735	96.73	3.8297	97.43
Weibull	a: 7.56897±4.85642 b: 0.00915±0.00748 c: 0.15632±0.00253 d: 109.5632±0.0167	53.61	11.2768	61.57
Logistic	a: 9.78421±5.73211 b: 0.00825±0.00963 c: 1.23678±0.00813	48.29	13.6853	45.72

Status of models according to the comparison criterion for root collar diameter growth of oriental beech juvenilities are shown in Table 2. According to Table 2, as Gompertz model is the highest with 98.35 R^2 value, Richards model followed this with the value of R^2=97.63. Despite that, Logistic and Weibull models have very low value of R^2 of 62.45 and 41.58 respectively. Mean error squares values are arranged as coefficient of specification. When we look at the efficiancy of the models, it is seen that while Gompertz and Richards models are efficient, Logistic and Weibull models are not efficient. In a similar research carried out in Norway natural forests by Fekeduleng et al. [11], it was determined that compared with Richards and Gompertz models, Logistic and Weibull models are not the most efficient ones. Karadavut et al. [16] have tried to define Richards, Gaussian and Logistic growth models for describing plants growth. As results, Richards's model described dry matter accumulation of silage and corn seeds better than Gaussian and Logistic growth models. Logistic growth equation described dry matter accumulation of silage and corn seeds worse than other growths. Logistic, Gompertz, Richards and Weibull growth models were tested on growth of different characters of rye plant. Characters measured were total fresh and dry matter upper ground and root fresh and dry weight. Results showed that root dry weight was modeled better by fitting Richards's model, however, for other characters Weibull model was better [15].

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

Models	Parameters	R^2	MES	ME
Gompertz	a: 5.48256±3.12564 b: 0.87569±0.00235 c:3.97521±0.00486	98.35	0.5468	0.97
Richards	a: 2.78234±1.00325 b:0.00155±0.00784 c:0.78941±0.00063 d:0.05237±0.00584	97.63	0.6798	0.95
Logistic	a: 2.14593±1.87546 b: 0.00476±0.00323 c: 1.23678±0.00813	62.45	0.5731	0.64
Weibull	a:9.63257±3.78941 b:2.45613±0.00698 c:0.38567±0.00423 d:0.98654±0.00096	41.58	17.6984	0.38

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 2001-2010 in the oriental beech natural regeneration area 56c division of Devrek-Akçasu Forest Range District, it arised that beech juvenilities under the dominant ecological conditions in the research area show 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 10 years, made an estimate in the level of various determinations. According to the estimated results made by the different mathematical models, it was determined that Gompertz is the model that shows the best prediction for height and root collar diameter growths of oriental beech juvenilities in the research area. In this context, Gompertz model will be used for error rate will be decreased as possible in carrying out the other maintenance techniques, especially stages of juvenility maintenance and selection applications in the right time.

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