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The Estimation of Regression Models for the Phytoplankton Growth

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Abstract: The regression equations were estimated to determine the cell number and chlorophyll-a content. First, the growth curves were formed and then the regression equations were estimated for *T. chuii* and *C. vulgaris*. *T. chuii* was cultured at different temperatures and both *T. chuii* and *C. vulgaris* were cultured at different illumination levels. At the end of the study, coefficients of determination (R^2) were found high and the parameters b and c were significant ($p < 0.01$) by the estimation equations. The regression models which were formed for *T. chuii* cultures at the temperatures 20, 24 and 27 °C are ln Y = 12 + 1.25 ln (n) − 0.0051 (n), ln Y = 11.9 + 0.817 ln (n) − 0.0408 (n), ln Y = 11.5 + 1.36 ln (n) − 0.0323 (n), respectively. The estimation equations for *T. chuii* and *C. vulgaris* cultures at the 17 and 77 μEm^{-2}s^{-1} light densities are ln Y = -0.724 + 0.106 ln (n) − 0.0334 (n) and ln Y = -0.460 + 0.867 ln (n) + 0.220 (n).

Key words: *T. chuii, C. vulgaris*, growth parameters, regression models

Introduction

In microalgae culture studies, growth can be measured quantitatively and qualitatively. In routine cultures, the phase of the growth cycle can be estimated from the colour of the culture. It can be sufficient to decide to add the fresh medium to the culture for semicontinuous systems or evaluate the position of cultures. However, we aren't informed about cell number and biomass. It is necessary to obtain more data for experimental studies. The cultures are evaluated quantitatively by measuring the cell number, optic density, wet and dry weight, the amount of chlorophyll-a, organic carbon which are the parameters related to the algal growth (Gökpinar and Büyükişik, 1994; Vonshak, 1986).

The closed systems are the simplest and the most extensive culture systems. Such a culture contains the characteristic phases, lag phase, exponential phase and stationary phase. When the microalgae species are used as experimental material for the physiological and biochemical researches the data which are obtained from the growth measurements indicate the activity of cells increasing and the numeric evaluation means the changes of unit cell mass. In the cell suspension of the growing culture, the total volume of cell increase with time and the increase is defined as growth.

In algal cultures, the growth rate is calculated by differential of dx/dt. In the formula, x can be the cell number, amount of carbon, nitrogen, chlorophyll-a and t is time. The growth is characterized as having at least four separate phases. Exponential or logarithmic phase is characterized by constant rapid cell division (Fox, 1983). Exponential phase limits and maximum cell division rate (km) can be calculated by the formula;

$$K = Log_2 X_2 − log_2 X_{1/} t_2 − t_1$$

Where, K is the exponential growth rate and X_1, X_2 are the numerical values for cell mass (given as dry weight, cell number, optical density etc.) at the beginning and end of the period, t_1 and t_2 mean corresponding times for X_1 and X_2 values (Guillard, 1975).

The marine microalgae species *T. chuii* (Prasinophyceae) and *C. vulgaris* (Chlorophyceae) were cultured at different light intensities and also *T. chuii* was cultured at different temperatures (Işik et al., 1999; Işik and Polat, 1999). In this study it was tried to estimate the growth parameters about the *T. chuii* and *C. vulgaris* cultures in exponential phase. For this purpose the cell numbers and the chlorophyll-a contents of the microalgae species were used.

Materials and Methods

The phytoplankton species, *T. chuii* (Prasinophyceae) and *C. vulgaris* (Chlorophyceae) were used in aquaculture, widely (Becker, 1995; Helm et al., 1979; Kumlu et al., 2001; Kumlu et al., 2000). The cells are single and their sizes are 3-5 μ and 13 −15 μ, respectively (Hoek et al., 1995). In batch culture system, 250 ml flasks and Conway medium were used for the cultures (Liao et al., 1983). The Thoma slide was used for cell counting and chlorophyll-a contents were determined according to Talling and Driver (Vollenveider et al., 1974).

In this study, multiple regression analysis method was used. At the same time this model was used by Wood (1967); Kayaalp and Bek, (1990).

$$Y = an^b e^{-cn} \quad (1)$$

Where;
Y: Chlorophyll-a or cell number,
n: Day,
a,b,c: Regression parameters.

The logarithmic transformation was applied to equation (1) and formed the equation (2).

$$ln Y = ln (a) + b ln (n) − c (n) \quad (2)$$

The parameters in equation were estimated, using the version 10.5 of MINITAB statistical package programme.

Results and Discussion

The Estimation of cell number of *T. chuii*: The chlorophyll-a contents of *T. chuii* cultured at the temperatures 20, 24 and 27 °C were estimated. The regression equations were estimated in turn as follows;
The equation of estimation for 20 °C,
ln Y = 12 + 1.25 ln (n) − 0.0051 (n)
The equation of estimation for 24 °C,
ln Y = 11.9 + 0.817 ln (n) − 0.0408 (n)
The equation of estimation for 27 °C,
ln Y = 11.5 + 1.36 ln (n) − 0.0323 (n)
The regression analysis tables of equation are given in Tables 1, 2, 3.
According to Table 1, the R^2 value of estimation equation at 20 °C was 98.1% and the regression equation and parameter b were significant ($p < 0.01$). However, parameter c was nonsignificant ($p > 0.01$).

Table 1: The regression analysis of culture at 20 °C.

S. V.	D. F.	S. S.	M. S.	F
Regression	2	18.0716	9.0358	393.77**
(b)	1	18.0700	18.0700	789.08**
©	1	0.0016	0.0016	0.07
Residual	15	0.3442	0.0229	
Total	17	18.4158		

**: $p < 0.01$

Table 2: The regression analysis of culture at 24 °C.

S. V.	D. F.	S. S.	M. S.	F
Regression	2	12.6303	6.3152	505.49**
(b)	1	12.5278	12.5278	1002.22**
©	1	0.1026	0.1026	8.21**
Residual	15	0.1874	0.0125	
Total	17	12.8177		

**: $p < 0.01$

Table 3: The Regression analysis of culture at 27 °C.

S. V.	D. F.	S. S.	M. S.	F
Regression	2	13.9563	6.9782	157.74**
(b)	1	13.9033	13.9033	314.554**
©	1	0.0530	0.0530	1.200
Hata	15	0.6193	0.0442	
Genel	17	14.5757		

**: $p < 0.01$

Table 4: The regression analysis of the chlorophyll-a content for the culture at 17μ Em^{-2}s^{-1}.

S. V.	D. F.	S. S.	M. S.	F
Regression	2	2.3429	1.1715	119.530**
(b)	1	2.1611	2.1611	220.520**
©	1	0.1818	0.1818	18.550**
Residual	21	0.2058	0.0098	
Total	23	2.5488		

**: $p < 0.01$

Table 5: The regression analysis of chlorophyll-a for the culture at 77μ Em^{-2}s^{-1}.

S. V.	D. F.	S. S.	M. S.	F
Regression	2	27.857	13.794	171.880**
(b)	1	17.248	17.248	215.600**
©	1	10.340	10.340	129.250**
Residual	23	1.8460	0.080	
Total	25	2.5488		

**: $p < 0.01$

It is seen from Table 2 that the R^2 value of estimation of equation at 24 °C was 98.5% and the regression equation and parameter b and c of the equation were significant ($p < 0.01$).

According to Table 3, the R^2 value of estimation equation for 27 °C was found 95.8% and regression equation and parameter b were significant ($p < 0.01$). However, parameter c was non significant ($p > 0.01$).

Table 4 indicates that the R^2 value of estimation equation for the culture at 17 μEm^{-2}s^{-1} was 91.9% and regression equation and parameter b and c in the equation were all significant ($p < 0.01$).

As clear from Table 5 the R^2 value of estimation equation for the culture at 77 μEm^{-2}s^{-1} was 83.4% and the regression equation and parameter b and c of the equation were significant ($p < 0.01$).

Estimation values which were obtained from regression equations for *T. chuii* at 20, 24 and 27 °C and the curves of estimated and examined values were formed. These curves given as Fig. 1, 2 and 3.

It is clear from Fig. 1 and 2 that estimated and examined values for 20 °C were similar but the deviation was observed for the culture at 27 °C after 10th day (Fig. 3). Deviation has also been observed in case of 24 °C as from Fig. 2. This is
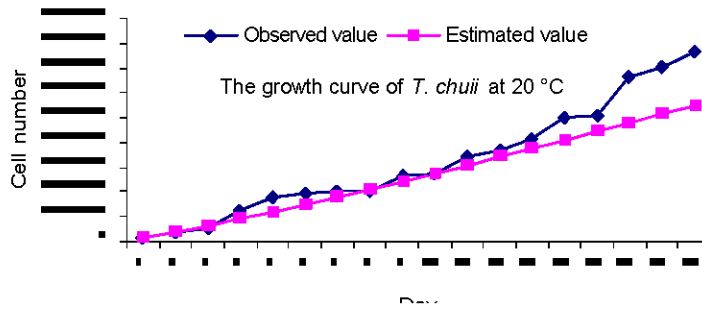

Fig. 1: The observed and estimated cell numbers of *T. chuii* cultures at 20 °C.
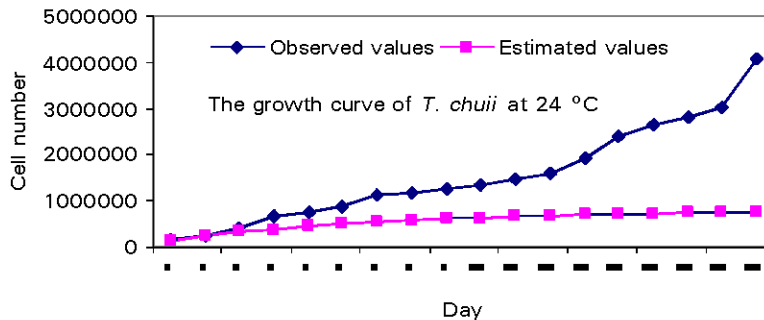

Fig. 2: The observed and estimated cell numbers of *T. chuii* cultures at 24 °C.
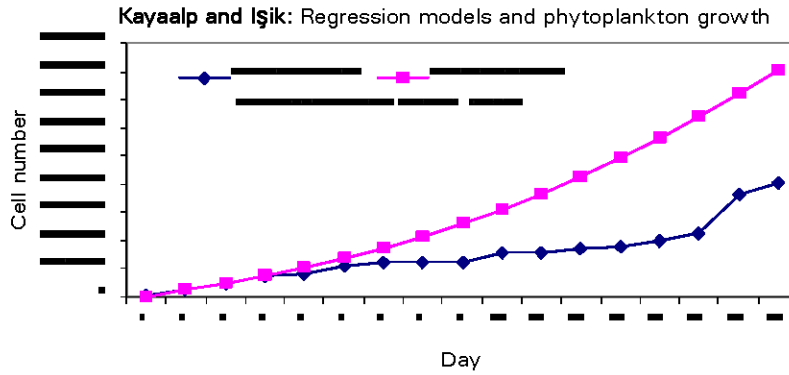
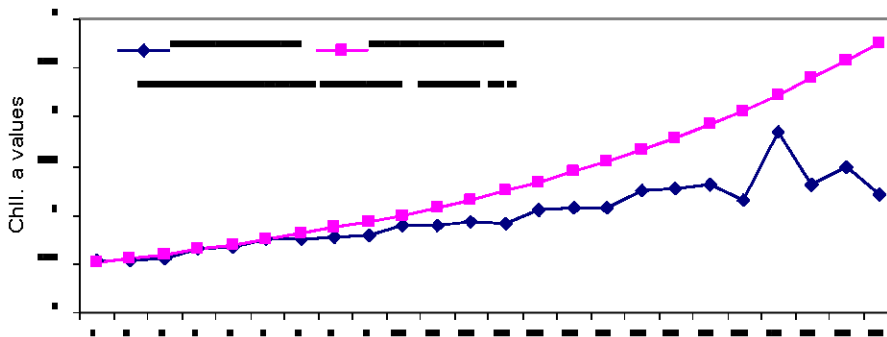Fig. 3: The observed and estimated cell numbers of *T. chuii* cultures at 27 °C.

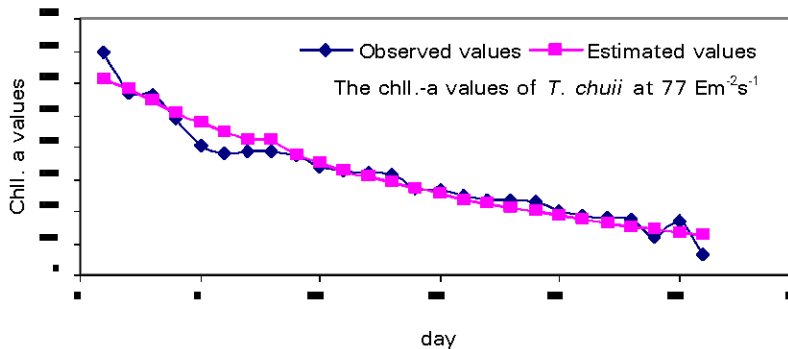Fig. 4: Observed and estimated chlorophyll-a contents for *C. vulgaris* culture at 17 μ_Em^{-2}s^{-1} light density.

Fig. 5: Observed and estimated chlorophyll-a contents for *T. chuii* culture at the 17 μEm^{-2}s^{-1} light density.

because, the regression coefficient of parameter c in the equation for culture at 27 °C is more biased than parameter c for the culture at 20 and 24 °C.

The Estimation of chlorophyll-a for *C. vulgaris* and *T. chuii*: Chlorophyll-a contents of *C. vulgaris* cultures at the light density of 17μ Em^{-2}s^{-1} and *T. chuii* cultures at the light density of 77 μ Em^{-2}s^{-1} were estimated. The estimation equations were formed for the observed contents.
The estimation equation for the culture in 17 μ Em^{-2}s^{-1} light density :

$$\ln Y = -0.724 + 0.106 \ln (n) - 0.0334 (n)$$

The estimation equation for the culture in 77 μ Em^{-2}s^{-1} light

density:

$$\ln Y = -0.460 + 0.867 \ln (n) + 0.220 (n)$$

The regression analysis related with the above regression equations are shown in Tables 4 and 5.
According to Table 4, the R^2 value of estimation equation for the culture at 17μ Em^{-2}s^{-1} was 91.9% and regression equation and parameter b and c in the equation were all significant ($p < 0.0$).
It is seen in Table 5 that the R_2 value of estimation equation for the culture at 77 μ Em^{-2}s^{-1} was 83.4% and the regression equation and parameters b and c of the equation were significant ($p < 0.01$).
According to Fig. 4, observed and estimated values were

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found similar until the 17th day but the deviation was observed later. From the results of this study it was found that the estimation equations could be used for the microalgae species to estimate the cell number and the chlorophyll-a content. Coefficients of determination (R^2) were found high and the parameters b and c in the regression equations were found important statistically for all the estimation equations.

Microalgae have an important role in mariculture as food for larval stages of crustaceans and fish, for all stages of bivalves and as food for zooplankton (rotifers, copepods and brine shrimps) which are fed to late larval and juvenile fish and crustaceans (Volkman et al., 1989). Technological advances have encouraged mass culture of microalgae and latest developments have established the potentiality of algae for the production of variety of compounds such as polysaccharides, lipids, proteins, carotenoids, pigments, vitamins, sterols, enzymes, antibiotics, pharmaceuticals and several other fine chemicals (Becker, 1995). Estimation equations can ensure the conveniences to the phytoplankton culturists. Counting the microalgae cells and determination of chlorophyll-a content are very difficult and time required. Using the equations can save time and avoid the chlorophyll-a analyses.

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