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On prognosis of growth of plants during control by lighting

EL Pankratov

Abstract
We describe a model to estimate efficiency of control of growth of plants during control by lighting. Consideration of the model gives a possibility to analyze dependence of the above growth on several factors. We obtain conditions to accelerate and decelerate of the considered growth. Also we introduce an analytical approach to make prognosis of the considered growth.

Keywords: Modeling of growth of plants, changing of speed of growth of plants, influence of lighting, analytical approach for modeling

Introduction
Effect of light on a plant could be divided on photosynthetic, regulatory- photomorphogenetic and thermal [1-7]. Light acts on growth through photosynthesis, which requires high levels of energy. At low quantity of light plants grow worse. Increasing of continuance of lighting leads to acceleration of growth of many plants. At the same time, the numerical values of the parameters of additional irradiation depend on the type of plant, the period of its development, as well as on the lighting parameters [3-7]. We described a model that gives a possibility to make prognosis of growth of the considered plants. Based on consideration of the model we obtained several dependences of growth of plant on lighting. We also consider an analytical approach to analyze the considered model.

Method of solution
To obtain the required results we consider saving energy law. For our case the considered law takes the form

$$\frac{dL}{dt} = \alpha(t)L^2 - \alpha(t)\beta(t)L^2 - \gamma(t)L^4 \quad (1)$$

The initial condition could be written as: $L(0) = 0$, because the initial linear dimension $L(t)$ of the considered plant is zero. Functions $\alpha(t)$, $\beta(t)$, $\gamma(t)$ describe the parameters of the considered processes; surface of crown (at consideration of a tree) is proportional to x^2; volume of plant is proportional to x^3. Term $\alpha(t)L^2$ in the equation (1) describes the energy obtained as a result of photosynthesis. The next in the same equation describes the energy consumption for the needs of photosynthesis. The third one describes the cost of transporting nutrient solution to all parts of the considered plant, which is proportional to the volume of the plant and height, since it is associated with overcoming gravity. The right term in the equation (1) shows the cost of increasing the mass of the plant. Now we present the equation (1) to the integral form

$$L = \int_0^t \alpha(\tau)L^2 d\tau - \int_0^t \alpha(\tau)\beta(\tau)L^2 d\tau - \int_0^t \gamma(\tau)L^4 d\tau \quad (2)$$

Next we solve the equation (2) by the method of averaging of function corrections [8-10]. To use the method for calculation of the first-order approximation of the linear dimension of a plant $L_1(t)$ we replace the considered function by the average value δ_1 in the right side of equation

[2]. The replacement leads to obtaining the relation to calculate the considered first-order approximation

$$L_1 = \delta_1^2 \int_0^t \alpha(\tau)\, d\tau - \delta_1^2 \int_0^t \alpha(\tau)\beta(\tau) d\tau - \delta_1^4 \int_0^t \gamma(\tau)\, d\tau \qquad (3)$$

Not yet known average value δ_1 was determined by using the relation [8-10].

$$\delta_1 = \frac{1}{\Theta}\int_0^{\Theta} L_1(t) dt \, . \qquad (4)$$

Using the relation (3) into relation (4) leads to the relation to calculate the considered average value δ_1

$$\delta_1^4 \int_0^{\Theta} \gamma(t) dt + \delta_1^2 \left[\int_0^{\Theta} (\Theta - t)\, \alpha(t) \beta(t) dt - \int_0^{\Theta} (\Theta - t)\, \alpha(t) dt \right] + \Theta \delta_1 = 0 \qquad (5)$$

The average value was calculated by the standard approach [11]. The solution leads to the following result

$$\delta_1 = \frac{1}{2}\sqrt{\sqrt[3]{\frac{1}{3}\sqrt{\frac{(3\Theta^2 - p^4)^3}{81} + \frac{(3\Theta^2 - p^4)^2}{4}} - \frac{q}{2}} - \sqrt[3]{\frac{1}{3}\sqrt{\frac{(3\Theta^2 - p^4)^3}{81} + \frac{(3\Theta^2 - p^4)^2}{4}} + \frac{q}{2}}}, \quad (6)$$

Where

$$p = \left[\int_0^{\Theta} (\Theta - t)\, \alpha(t) \beta(t) dt - \int_0^{\Theta} (\Theta - t)\, \alpha(t) dt \right] \Big/ 2 \int_0^{\Theta} \gamma(t) dt \, .$$

The second-order approximation of the linear dimension of a plant $L_2(t)$ was calculated by standard replacing of the required function L (t) on the following sum $L_2(t) \to \delta_2 + L_1(t)$) in the right side of the equality (2) [11]. After the replacement we obtain the relation to calculate the considered second-order approximation

$$L_2 = \int_0^t \alpha(\tau)(\delta_2 + L_1)^2 d\tau - \int_0^t \alpha(\tau)\beta(\tau)(\delta_2 + L_1)^2 d\tau - \int_0^t \gamma(\tau)(\delta_2 + L_1)^4 d\tau$$

(7)

Not yet known average value δ_2 was calculated by the relation [8-10].

$$\delta_2 = \frac{1}{\Theta}\int_0^{\Theta} [L_2(t) - L_1(t)] dt \, . \qquad (8)$$

Using values (3) and (7) into integral (8) leads to the equation

$$a_4 \delta_2^4 + a_3 \delta_2^3 + a_2 \delta_2^2 + a_1 \delta_2 - a_0 = 0 \, , \qquad (9)$$

Where

$$a_4 = \frac{1}{\Theta}\int_0^{\Theta} (\Theta - t)\gamma(t)\, dt \, ,$$

$$a_3 = \frac{4}{\Theta}\int_0^{\Theta} (\Theta - t)\gamma(t) L_1(t) dt \, ,$$

$$a_2 = \frac{1}{\Theta}\left\{ 6\int_0^{\Theta} (\Theta - t) L_1^2(t) \times \right.$$

$$\left. \times \gamma(t) dt - \int_0^{\Theta} \alpha(t)[1 + \beta(t)](\Theta - t) dt \right\} ,$$

$$a_1 = \frac{2}{\Theta}\left\{ \frac{\Theta}{2} + 2\int_0^{\Theta} (\Theta - t)\gamma(t) L_1^3(t) dt - \int_0^{\Theta} (\Theta - t) \times \right.$$

$$\left. \times \alpha(t)[1 + \beta(t)] L_1(t)\, dt \right\} ,$$

$$a_0 = -\frac{1}{\Theta}\int_0^{\Theta} (\Theta - t)\left\{ \delta_1^4 \gamma(t) - \alpha(t)[1 + \beta(t)]\delta_1^2 - L_1^4(t) \times \right.$$

$$\left. \times \gamma(t) \right\} dt - \frac{1}{\Theta}\int_0^{\Theta} (\Theta - t)\alpha(t)[1 + \beta(t)] L_1^2(t) dt \, .$$

Solution of the above equation by the standard approach [11] leads to the following result

$$\delta_2 = -\frac{a_3}{4a_4} + \frac{1}{2}\sqrt{\frac{a_3^2}{4a_4^2} - \frac{2a_2}{3a_4} + \frac{a_4(a_2^2 - 3a_3 a_1 - 12 a_4 a_0)}{3(2a_2^3 - 9a_3 a_2 a_1 + 27 a_4 a_1^2 - 27 a_3^2 a_0 + 72 a_4 a_2 a_0)}} \qquad (10)$$

Discussion

Now we consider growth of plants as a function of growth time with changing of values of the considered parameters. Figure 1 presents several dependences of height of plants on time at constant values of α, β and γ. Larger values of the considered parameters correspond to larger numbers of curves. Variation of the above parameters on time could leads to variation of velocity of growth of plants.

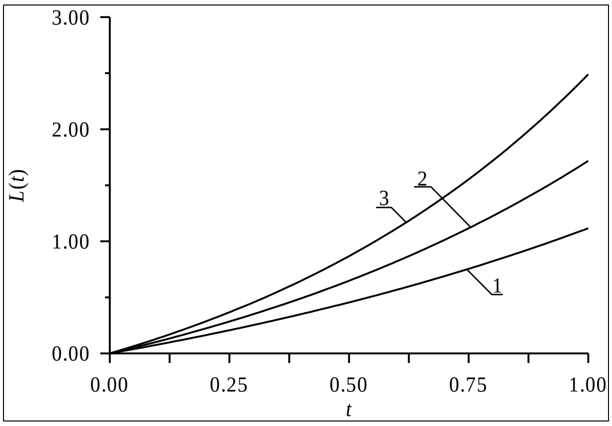

Fig 1: Typical variations of height of plants on time at constant values of α, β and γ. Larger values of the considered parameters correspond to larger numbers of curves

Conclusion

We introduced and analyzed a model growth of plants under influence of changing of irradiation of light. Based on the model we analyzed possibility to control of the considered process. Also we analyzed possibility to make the considered prognosis analytically.

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