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On Prognosis of Growth of Plants During Control by Lighting

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***Abstract*: In this paper we introduce a model to estimate efficiency of control of growth of plants during control by lighting. Based on analysis of the model we analyzed dependence of growth of plants on several factors. We formulate recommendations to accelerate and decelerate of growth of plants. We also introduce an analytical approach for prognosis of the above growth.**

***Keywords*: Prognosis of Growth of Plants, Changing of Speed of Growth of Plants, Influence of Lighting, Analytical Approach for Analysis.**

I. INTRODUCTION

Effect of light on a plant could be divided on photosynthetic, regulatory- photo morphogenetic 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]. In this paper, we introduce a model that gives a possibility to make prognosis of growth of plants [12][13]. Based on analysis of the model we analyzed dependence of plant growth on lighting. An analytical approach for analysis the above model was also introduced.

II. METHOD OF SOLUTION

To solve our aim we consider saving energy law. In theour case the considered law could be written as

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

with initial condition $L(0) = 0$. The following notations were introduced in the equation (1): $L(t)$ is the linear dimension of the considered plant; $\alpha(t)$, $\beta(t)$, $\gamma(t)$ are 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. The first term in the right side of 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 last term in the right side of the considered equation describes the cost of increasing the mass of the plant. Now we transform the equation (1) to the following integral form

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

Next we solve the equation (2) by the method of averaging of function corrections [8-10]. In the framework of the method to obtain the first-order approximation of the linear dimension of a plant $L_1(t)$ we replace the considered function by not yet known average value δ_1 in the right side of equation (2). The replacement gives a possibility to obtain the following equation to determine 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 calculated by the following standard relation [8-10][15]

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

Substitution of relation (3) into relation (4) gives a possibility to obtain the following equation to calculate the considered average value δ_1

$$\delta_1^2 \left[\int_0^\Theta (\Theta - t)\,\alpha(t)\beta(t)\,dt - \int_0^\Theta (\Theta - t)\,\alpha(t)\,dt\right] +$$

$$+ \delta_1^4 \int_0^\Theta \gamma(t)\,dt + \Theta\,\delta_1 = 0 . \qquad (5)$$

Solution of equation (5) in the framework of the standard procedure [11] gives a possibility to obtain the following relation to determine the above average value δ_1

$$\delta_1 = \frac{1}{2}\left[\sqrt[3]{\frac{1}{3}\sqrt{\frac{\left(3\Theta^2 - p^4\right)^3}{81} + \frac{\left(3\Theta^2 - p^4\right)^2}{4}} - \frac{q}{2}} - \right.$$

$$\left. - \sqrt[3]{\frac{1}{3}\sqrt{\frac{\left(3\Theta^2 - p^4\right)^3}{81} + \frac{\left(3\Theta^2 - p^4\right)^2}{4}} + \frac{q}{2}}\right], \qquad (6)$$

where $p = \left[\int_0^\Theta (\Theta - t)\,\alpha(t)\beta(t)\,dt - \int_0^\Theta (\Theta - t)\,\alpha(t)\,dt\right] \times$

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

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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 sum of average value of the considered approximation and approximation with the previous order (i.e. $L_2(t) \to \delta_2 + L_1(t)$) in the right side of equation (2) [11]. The replacement gives a possibility to obtain equation to calculate the considered second-order approximation in the following form

$$L_2 = \int_0^t \alpha(\tau)(\delta_2 + L_1)^2 d\tau - \int_0^t \alpha(\tau)\beta(\tau)(\delta_2 + L_1)^2 d\tau - -\int_0^t \gamma(\tau)(\delta_2 + L_1)^4 d\tau . \quad (7)$$

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

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

Substitution of relations (3) and (7) into relation (8) gives a possibility to obtain equation to determine average value δ_2

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

where $a_4 = \frac{1}{\Theta}\int_0^\Theta (\Theta - t)\gamma(t) dt$, $a_3 = \frac{4}{\Theta}\int_0^\Theta (\Theta - t)\gamma(t)L_1(t) dt$,

$$a_2 = \frac{1}{\Theta}\left\{6\int_0^\Theta (\Theta - t)L_1^2(t)\gamma(t) dt - \int_0^\Theta \alpha(t)[1 + \beta(t)](\Theta - t) dt\right\},$$

$$a_1 = \frac{2}{\Theta}\left\{\frac{\Theta}{2} + 2\int_0^\Theta (\Theta - t)\gamma(t)L_1^3(t) dt - \int_0^\Theta (\Theta - t)[1 + \beta(t)] \times \right.$$

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

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

$$\times\, \alpha(t)L_1^2(t) dt .$$

Solution of equation (9) in the framework of the standard procedure [11][16] gives a possibility to obtain the following relation to determine the above average value δ_2

$$\delta_2 = \left[\frac{a_4\left(a_2^2 - 3a_3a_1 - 12a_4a_0\right)}{3\left(2a_2^3 - 9a_3a_2a_1 + 27a_4a_1^2 - 27a_3^2a_0 + 72a_4a_2a_0\right)} + \right.$$

$$\left. + \frac{a_3^2}{4a_4^2} - \frac{2a_2}{3a_4}\right]^{\frac{1}{2}} \frac{1}{2} - \frac{a_3}{4a_4} . \quad (10)$$

III. DISCUSSION

In this section we analyzed growth of plants with time with variation of different parameters. Fig. 1 shows typical dependences of dimensions of plants on time at constant values of the recently considered parameters α, β and γ. Increasing of number of curves corresponds to increasing of values of the above parameters. Changing with time of the parameters α, β and γ leads to changing of speed of growth of plants with time. The changing of the above speed of growth depends on type of dependency of the above parameters on time.

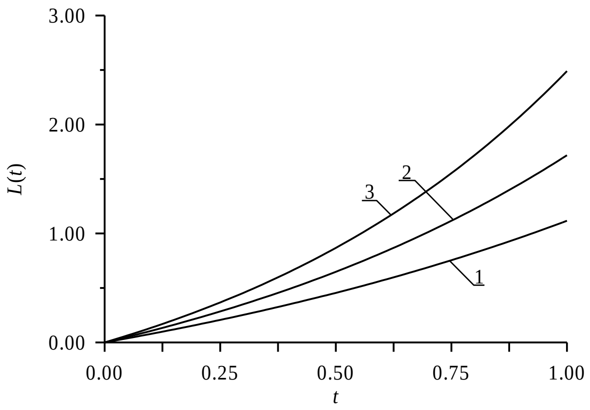

Fig. 1. Typical Dependences of Dimensions of Plants on time at Constant Values of the Recently Considered Parameters α, β and γ. Increasing of Number of Curves Corresponds to Increasing of Values of the Above Parameters

IV. CONCLUSION

In this paper we formulate a model for prognosis of growth of plants. Based on analysis of the above model we analyzed dependences of growth of plants on different factors: we analyzed possibility to accelerate acceleration and deceleration of growth of plants. We also introduce an analytical approach for prognosis of the above growth.

DECLARATION STATEMENT

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Authors Contributions	I am only the sole author of the article.

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AUTHOR PROFILE

Evgeny Leonidovich Pankratov was educated Nizhny Novgorod state university (Nizhny Novgorod city, Russia) with full doctor degree in physics and mathematics. Now he has a position of a full professor. Area of scientific interests of Evgeny Leonidovich Pankratov is prognosis of processes in physics, biology and economics with appropriate development of models and analytical approaches for solution of equations, which were used in the considered models. Now he have 580 published papers in area of his research.