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Model Construction and Visualization Simulation of Soybean Root System

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Abstract: This paper mainly focused on the growth law, model construction and visualization of a soybean root. A pot experiment was conducted in the laboratory to collect root system data and measure soybean root's length, diameter and number by excavating in different periods. On the basis of an in-depth analysis of root structure geometry, we analyzed the collected experimental data with logistic equations, and got the growth of soybean root equation, according to its morphological structure characteristics of self-similarity, and discussed the virtual modeling method on the soybean root based on L-system and in Visual c++ Using OpenGL technology to achieve a soybean root system topology model and visualization simulation.

Key words: soybean root, visualization simulation, OpenGL
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Introduction

With the improvement of computer hardware technology and the rapid development of computer graphics, virtual plant has been a new research field. Virtual plant research, the most important and key point is to obtain the data information and build topology model of plant growth, so as to realize visual simulation of plant morphological structure on computer.

Soybean root is one of the most important organs of soybean. It takes important effects on the growth and development, physiological function and metabolism of the soybean. Because of the particularity of the root growth environment, it makes the study of root crops far lagging behind that on the ground. Virtual plant overcomes the disadvantages of taking a long time on experiment and other environmental factors beyond our control. Hence, it is significant to study the root of the plant in visualization method.

Morphological Features and Growth Characteristics of Soybean Root System

Composition of soybean root system

The root of soybean was taproot. It was made up of main root, lateral root and adventitious root. The main root was formed by elongation of soybean seed radices, and lateral root was the branch produced by the main root. Main root produced the first lateral root, and the first lateral root produced the secondary lateral root, and so forth.

Soybean root system was concentrated in the 5-20 cm plough layer, main root growth thick within 7-8 cm under surface, and the main lateral root was concentrated here. The main root suddenly became thin here, and difference with lateral root was not obvious, linear main root under 20 cm could be depth of

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1 m. Lateral root derived from the main root parallel extended to surrounding, and could be extended up to 40-50 cm, meanwhile, the new lateral root was generated.

Growth rhythm of soybean root system

The growth of soybean root indicated s-shaped curve and its growth was a "slow-fast-slow" process. Seedling root was made up of a number of similar parallel to the expansion of the branch roots and the main root of the vertical growth component. Since the beginning in squaring period, after a large number of lateral roots having been produced, their growth has been turning from the parallel expansion of the beginning of a downward to the vertical growth. The growth of new root of soybean root system stopped in seed filling stage. In this case, soybean root system would present bell-shaped distribution. Soybean root growth process met logistic function. Logistic equation provided an effective solution to s-shaped curve in the growth as a described in a mathematical model theory.

Topological Model Construction of Soybean Root System

Logistic equation

Logistic equation was derived by biological mathematician Verhulst in 1938 to study the process of population growth. It was characterized by the slow growth in the beginning, and the subsequent rapid growth in a certain range, to a certain extent, the growth slowed down. It had obvious advantages especially in describing the growth of the number of organisms changing. Soybean root growth curve was s-shaped and its growth met the logistic equation.

Deductive procedure of logistic equation

We assumed that there was no energy loss in the growth process, which was $W+S$=Constant=$W_0+S_0=W_m+S_m=C$. W_0 and S_0 was the initial value of W and S in time t=0, W_m and S_m was the final value of W and S as t tended to infinite (we assumed that it finally reached a steady state), and C was a constant.

The growth rate was written as a function of W and S, the following expression could be expressed as:

$$\frac{dW}{dt}=h(W, S) \tag{1}$$

The $S=C-W$ was substituted into the equation, and there were:

$$\frac{dW}{dt}=h(W, C-W)=f(W) \tag{2}$$

Where, f was a function of the single variable W, which was the basic form of the growth equation. Here was the basic form of the logistic, assumed that it was proportional to the growth rate and dry weight W, and was proportional to S, the growth was irreversible, and there were:

$$\frac{dW}{dt}=KWS \tag{3}$$

K was a constant, the $S=W_m-W$ was substituted into the equation as S_m=0, and there were:

$$\frac{dW}{dt}=KW(W_m-W) \tag{4}$$

The $K=\mu/W_m$ was substituted into the equation, and there were:

$$\frac{dW}{dt}=\mu W(1-\frac{W}{W_m}) \tag{5}$$

After integral, the following expression could be expressed as:

$$W=\frac{W_0W_me^{\mu t}}{W_m-W_0+W_0e^{\mu t}} \tag{6}$$

The more common form of logistic equation was written as:

$$W=\frac{W_0W_m}{W_0+(W_m-W_0)e^{-\mu t}}=\frac{W_m}{1+Ke^{-\mu t}} \tag{7}$$

Logistic curve

The basic form of deductive logistic equation was

$$W=\frac{W_m}{1+Ke^{-\mu t}}$$

Parameters K and μ were empirical parameters. They could only be determined by the logistic equation fitting based on data obtained. In the derivation of the logistic equation, parameters K and μ could be