ABSTRACT

of the dissertation research of G. Kim on "Development of mathematical models and algorithms for automatic control of the productivity of medicinal plant growth in the conditions of hydroponic systems", submitted for the degree of Doctor of Philosophy (PhD) in the specialty: "6D075100 - Informatics, computer engineering and control"

Relevance of the work. The accelerated development of information technologies, computer technology and the success of mathematical disciplines provide new opportunities for scientists to develop a method for controlling productive processes of plants. Timely detection and accurate diagnosis of a lack of plant nutrition can prevent crop decrease. In this regard, during the growing season of medicinal plants, sites are inspected, leaves are selected and their morphological parameters are visually evaluated according to the test method for distinctness, uniformity and stability. Visual assessment is subjective and uninformative, which affects the correctness and timeliness of the diagnosis of deviations from the norm.

In solving this problem, it is important to develop a more advanced information and analytical method for assessing the morphological parameters of medicinal plant leaves using a computer installation for automated assessment of possible deviations from normal growth.

The method of productivity control should be based on mathematical models of production processes, which include photosynthetic activity of plants, growth and accumulation of biomass. Currently, it is important to develop a method of productivity control for crop production in protected soil, artificial climate installations and in hydroponics conditions. The main task of greenhouse improvement of crop production is the production of plants regardless of the time of year. The most promising method for rationally using the territory and reducing labor costs is the method of cultivation on low-volume hydroponics. The low-volume technology of growing plants in greenhouses provides for the creation of optimal water-air, nutrient, temperature parameters in the root zone of plants.

In this regard, **the purpose** of this dissertation is to develop mathematical models and algorithms for automatic control of the productivity of medicinal plant growth in the conditions of hydroponic systems.

Research objectives:

– to investigate existing approaches to modeling plant growth in the conditions of hydroponic systems;

– to investigate the results of the application of image recognition systems for automating the process of classification of objects of crop production;

– to develop a mathematical model of the productivity of the growth of a medicinal plant depending on changes in the parameters of the system;

– to develop a method for recognizing the causes of deviations in plant development using machine learning capabilities;

– to carry out an interpretation and a meaningful study of the results of recognition of the causes of deviations in the development of the Aloe Arborescens L. plant;

– to develop an automatic growth control module to provide the main feedback in an automated control system for the growth of medicinal plants;

– to develop an algorithm for controlling the automated growth of medicinal plants in the conditions of hydroponic systems and a block diagram of information and analytical support for the cultivation of medicinal plants;

– develop an intuitive interface for automated plant growth management.

The object of the study is the growth of the medicinal plant Aloe Arborescens L.

The subject of the research is the processes of monitoring and control of the productivity of the growth of medicinal plants in the conditions of hydroponic systems (models, methods and algorithms of the process of monitoring and control of the productivity of the growth of medicinal plants in the conditions of hydroponic systems).

Research methods. Methods of parametric identification, methods of processing and analysis of experimental data, simulation modeling methods, machine learning methods were used in the process of dissertation research.

Scientific novelty:

– A mathematical model of the growth of the medicinal plant Aloe Arborescens L. has been developed taking into account two main factors affecting the growth of the plant;

– A classifier model has been developed that allows using the VGG16 neural network to solve the problem of automatic classification of Aloe Arborescens L. plants;

– A block diagram of information and analytical support for growing medicinal plants has been developed;

– An automatic growth control module has been developed, which, based on the results of growth modeling and classification of Aloe Arborescens L., allows for the main feedback in an automated control system for the growth of medicinal plants.

Theoretical significance.

The results of the study of the logistic growth model, the classifier model and the automatic growth control module of Aloe Arborescens L. can be used in the study of various aspects of the functioning of plant organisms, finding the cause and effect of certain processes, making forecasts, as well as for the development of automated control systems for plant growth in hydroponic systems.

Practical significance.

The developed algorithm for automatic assessment of morphological parameters of a medicinal plant will create the basis for further development and improvement of technological processes of vegetation. The use of computer recognition of deviations from normal plant growth will increase the efficiency of agricultural technologies by reducing labor costs and the accuracy of assessing the qualitative characteristics of plants.

The provisions of the dissertation submitted for defense:

– mathematical model of the growth of the Aloe Arborescens L. medicinal plant in the conditions of hydroponics;

– classifier model for automatic classification of Aloe Arborescens L. plants;

– module for automatic growth control of the Aloe Arborescens L. medicinal plant;

– a block diagram of an adaptive control system for the growth rate of the Aloe Arborescens L. plant with a reference model;

– algorithms for controlling the growth of Aloe Arborescens L. in the conditions of hydroponic systems;

– intuitive interface for automatic control of plant growth.

Approbation of the work.

The results of the dissertation research were reported and discussed at scientific conferences:

– VI International Student Scientific and Practical Conference «Youth and Science-2019» NKSU named after M.Kozybayev (2019).

– VII International scientific and practical conference «Global Science and Innovation 2019: Central Asia» as part of the publication of «GLOBAL SCIENCE AND INNOVATIONS 2019: CENTRAL ASIA» International Scientific Journal, Nur-Sultan, Kazakhstan, September 25-28 (2019).

– International Scientific and Practical conference "Standardization - a tool for improving the competitiveness and integration of Kazakh products into the world economy", Nur-Sultan, Kazakhstan, November 24 (2019).

Publications.

7 scientific articles have been published on the topic of the study, including 3 articles in collections of international conferences, 3 articles in journals recommended by Committee for quality assurance in the field of education and science of the Ministry of education and science of the Republic of Kazakhstan, 1 article in a journal indexed in the SCOPUS database, and 1 copyright certificate for an intellectual property object has been obtained.

The personal contribution of the author is to conduct research substantiating the main provisions submitted for the defense, as well as the author also played a significant role in the generalization and analysis of the results.

The structure of the dissertation. The dissertation has a classical structure: an introductory part, the main part (four chapters), a conclusion, a list of sources used and appendices. The work is presented on 122 pages of computer text, includes 28 figures, 17 tables and 98 titles of bibliographic sources.

In the introduction, the choice of the research topic is justified, the relevance of the development of a method for controlling the productivity of medicinal plant growth in hydroponic systems is revealed, the purpose of the study is formulated, its tasks are determined, the object and subject of the study are presented, the scientific novelty and practical significance of the work are disclosed.

In the first chapter, a study of existing theoretical approaches to the mathematical description of production processes, to modeling the dynamics of the

accumulation of plant biomass and biologically significant elements in vegetative organs is carried out. The next step is to study the specifics of growing medicinal plants by hydroponic methods, namely, the growth conditions of the most common medicinal plants are investigated, the experience of using hydroponics in plant cultivation is considered and the analysis of international experience in the creation and control of automated hydroponic devices of major world manufacturers is carried out. Also, the use of pattern recognition systems for automating the process of classifying objects of crop production and identifying deviations in plant development has been investigated.

In the second chapter, the applicability of the logistic model to describe the growth process of the Aloe Arborescens L. plant is experimentally proved, taking into account the influence of external factors. Based on experimental data, a logistic model was parameterized and a reference S-shaped curve was constructed. The resulting mathematical model will be useful in calculating the optimal harvest time and in observing the trend of plant growth. Thus, an acceptable method is proposed that is able to calculate the area of the leaf surface. At the same time, comparing the current value with the reference value, we can conclude about the state of plant growth.

In the third chapter, a method for recognizing the causes of deviations in the growth development of the Aloe Arborescens L. plant using machine learning capabilities has been developed. The process of preparing experimental samples for neural network training is described. The results of approbation and research on the development of a model of automatic classification of plants by the type of deviation in its development are presented. It is concluded that the developed system can be used to implement the main feedback of the automatic control system of the hydroponic installation.

The fourth chapter is devoted to algorithms for controlling the automated growth of medicinal plants in the conditions of hydroponic systems using the results obtained in the second and third chapters. A block diagram of an adaptive control system for the growth rate of the Aloe Arborescens L. plant with a reference model (an object for which a copyright certificate has been obtained) is presented. The organization of the automated operation of the hydroponic system is described using the architecture of data collection and processing.

In conclusion, the research results are presented, including the main conclusions based on the results of the dissertation research.