Technical support by automated control system for ecological-technological processes of crop growing in conditions of protected ground

V N Pryahin¹, M A Karapetyan², and V V Ilinich³

¹ Institute of Systems Analysis and Management, State University "Dubna", 19, Universitetskaya st., City Dubna of Moscow region, 141980, Russian Federation
² Institute of Mechanics and Energy, Russian State Agrarian University - Moscow Timiryazev Agricultural Academy, 49, Timiryazevskaya st., Moscow, 127550, Russian Federation
³ Department of Meteorology and Climatology, Russian State Agrarian University - Moscow Timiryazev Agricultural Academy, 49, Timiryazevskaya st., Moscow, 127550, Russian Federation

E-mail: vilinitch@gmail.com

Abstract. The article is dedicated to the study of methods and means of automated system control of ecological and technological processes of plants in protected ground conditions. The key concepts and main directions of the study include: development and substantiation of a conceptual scheme for managing crop cultivation technologies and application of information technologies that take into account the ecological and technological state of the crop production facility. Automated control systems were compared in terms of deterministic and stochastic modes with respect to quality indicators of greenhouse microclimate parameters. The main factors have been characterized for the growth and development of plants in protected ground conditions. A comparative analysis of fully and partially automated systems that control the microclimate in greenhouses has been made. A block scheme was proposed for the control over the technological process, taking into account the automation of plant growing and the results of forecasting the conditions of emergencies. The technical means have been offered for automated control of technological processes of crop production, which allow obtaining the added effect. The ways of improving the automated control system with the help of technical means were outlined for increasing the qualitative and quantitative characteristics of the crop in the greenhouse, taking into account the economic efficiency of the planned activities.

1. Introduction

In recent decades, the intensification of greenhouse production has increased and has made a significant contribution to meeting the growing demand for resource-intensive diets [1]. Greenhouse farming helps create jobs and stimulates the service sector in different regions [2], even in the southern regions. The conducted studies emphasize the importance of growing soilless cultural [3], integrated control of microclimate factors, creating vertical agrosystems in urban and rural areas, rational use of energy [4–6], development of materials and constructions [7, 8] and the use of information technology [9]. These scientific areas are capable of optimizing the overall global production and adding jobs. At the same time, we must remember that many greenhouses are very small, and their owners are small farmers with limited resources to buy new equipment and expensive technologies.
The relevance of research in the field of creating new information systems for managing crop production technologies is due to stringent technological requirements and economic constraints imposed on modern agricultural production.

Accordingly, the purpose of the study is to develop a conceptual scheme for managing crops cultivation technologies based on information and instrumental technologies, taking into account processes that have a high degree of automation when growing crops in greenhouses.

The following problems have been solved within the framework of the study:
- analysis of existing management systems for agricultural technologies and setting the task of managing the processes of production of crop products based on the use of effective information technologies and tools;
- development of a structural scheme for managing the technological process of crop production, taking into account the automation of crop production and the results of forecasting emergencies.

2. Methods and materials.

Currently, technologies for growing vegetables and flowers require maintaining optimal microclimate regimes in greenhouses [10–12]. The cultivation of agricultural products in an artificial microclimate is one of the most energy-intensive industries and has a complex technology. The yield and quality of products depend on various factors. All the main factors for plant growth and development are represented in Figure 1.

![Figure 1. The main factors for plant growth and development.](image)

It was determined that the following factors are most significant: temperature, air humidity, illumination, watering, plant feeding, airing.

3. Results

A theoretical analysis of phenomena, technological processes and the functioning of technical systems at enterprises of the agro-industrial complex is based on the choice of certain models or calculation schemes. Accordingly, it is advisable to consider two options for the functioning of automated control systems for the supply of the working environment (WS): on the basis of an electrohydraulic distributed device, operating in a deterministic mode of the servicing consumer (Figure 2); and on the basis of electromagnetic valves, realizing the function in the stochastic (random) mode (Figure 3).

A deterministic process means that all factors influencing the development of a decision-making situation are uniquely determined and their values are known at the time of decision-making. For example (in the system in Figure 2), all consumption objects (greenhouses or areas of greenhouses) are served in a predetermined mode, that is, sequentially. At the same time, a stochastic process assumes the presence of elements of uncertainty (Figure 3) and takes into account the possibility of a probabilistic distribution of factors and parameters that determine the development of the situation. In this case, objects are serviced in a random process, when there are signals from sensors that react to changes in the microclimate in the greenhouse.

Growing plants in greenhouses can be divided into two categories: industrial production and personal subsidiary plots in rural areas. There are two types of microclimate control operation: partially automated and fully automated. Modern greenhouse complexes are multi-span according to standard designs, they are equipped with the necessary engineering systems for maintaining a microclimate: heating, irrigation, ventilation and air circulation, water supply and sewerage, lighting. All of these systems designed for large
enterprises. They are difficult to install and operate, and are expensive. These systems are not applicable to private or smallholder farms. The alternative is partially automated installations. They are a combination of manual control and partial automation. So cost is not high [11]. Table 1 shows examples of such installations used in life support systems for training cosmonauts, as well as in private household plots.

We carried out an analysis to identify technological components and characteristics that meet the questions and objectives during many years of research [6]. Table 2 contains examples not only in terms of technological components, but also of inventions that were the result of such an analysis.

**Table 1.** The main characteristics of the partially automated installations.

| Invention title | Purpose of invention | Technical elements | Authors and references |
|-----------------|----------------------|--------------------|------------------------|
| Device of control by irrigation system. | Simplification of design and increasing functioning velocity. | External simulator; pump; distributor; comparison element; time relay; units: of commands, of model selection, of distributor control, of pump control. | Pryahin V.N., Sabashvily R.G., Zuev I.V. Certificate of authorship 05.11.1979. Bulletin No. 41. |
| Device for humidifying and cooling air in a greenhouse. | Improving humidification quality and temperature control efficiency. | Air fan; heater; spray-humidifier; moisture collector; separator; working chamber; rate dispenser regulator; ion filter. | Pryahin V.N., Sabashvily R.G., Strel’tsov V.A. et al. Certificate of authorship: SU 625657A1; 30.09.1978; Bulletin No. 36. |
| Device for soilless plant cultivation. | Providing lighting control depending on the growing season of plants. | Sabavilv G.R., Pryahin V.N., Glebovich A.A et al. Certificate of authorship: SU 47706A1; 25.07.1975. Bulletin No. 27. |
|--------------------------------------|-------------------------------------------------------------------|-------------------------------------------------------------------|
| Device for regulating an electric power unit. | Simplification of the scheme for design of the device and increasing the reliability of its operation. | Burobin V.N., Pryahin V.N., Zuev I.V. et al. Certificate of authorship: SU 691828A1; 15.10.1979. Bulletin No. 38. |
| Automatic electrical regulator for the flow rate of environment, which cools the tubular gas discharge lamp. | Ensuring normal operation of the lamp with optimal consumption of the cooling environment (installation simulating the Sun and (or) the radiation of the Earth). | Anisimov O.A., Voronin G.N., Pryahin V.N. et al. Certificate of authorship 215329A1; 03.04.1968. Bulletin No. 13. |
| Device for growing plants on aero-phonics. | Economical use of aerosol and a decrease in the specific energy consumption of the plant nutrition process per unit area. | Baydukin Yu. A., Sabavilv G.R., Pryahin V.N., Baydukina G.V. Certificate of authorship SU 296528A1; 02.03.1971. Bulletin No. 9 |
| Device for regulating the external environment factors during growing plants. | Ensuring the simultaneous receipt of a crop of the same quality throughout the area with minimal additional lighting. | Pryahin V.N., Maksimov V.M., Ovchukova S.A. Utility model patent RU 157254. 27.11.2015 Bulletin No. 33 |
| Device for distributing the environment to independent consumer objects. | Improving the quality of dosing of the working environment while reducing power consumption. | Pryahin V.N., Maksimov V.M., Rikov S.V. Utility model patent RU 163137. 10.07.2016 Bulletin No. 19 |
| Device for distributing liquid or gaseous environment to the independent objects of consumption. | Expansion of the functionality for the switchgear. | Pryahin V.N., Sokolov V.V, Utility model patent RU 2409785. 20.01.2011 Bulletin No. 2 |
Table 2. Examples of technology-application structuring for innovative solutions.

| Conditions for the innovative technology | Decision | Invention |
|------------------------------------------|----------|-----------|
| Supporting temperature of the heat carrier fluid | Mechanical regulator based on the movement of the stem that controls the inlet valves | Controller of the temperature coolant RU No. 608131 |
| Availability of cold and hot coolant reserves | Pressure change compensator due to additional spring | Locking device RU No. 613619 |
| Reliable sealing of the chamber opening with liquid or gas under pressure. | Temperature changes affecting the force of the closing spring pressure | Electrical signal device consisting of flow direction micro-switches and a spring loaded cam on the shaft |
| The need to obtain information about the current direction of flow through the switchgear. | The distribution of the flow of liquid or gas by a mechanical drive based on a rotary shaft | Signalling device to the switchgear. Utility model patent RU No. 317850 |

We can see from the table that the structuring of the object of innovative technology, its functional usefulness (applied side and manufacturability) reflect both specific solutions and are typical representations of the corresponding innovative technologies. Moreover, each of them separately (input, process, output, applied technology, solution) can be considered as a conditional information unit for multivariate solutions, regardless of whether all these components will be used or only some of them. At the same time, we can note the following main properties of the components, regardless of the nature and type of technology.

According to the "input", this is a homogeneous representation of the characteristics of the initial situation (for information technology, it is the reliability and representativeness of the data in relation to the given amount of data). For example, for a gas mixture, there are regularities in the distribution of composition and volumes, dynamics of changes in flows, etc.

"Process" is the means, methods, technology itself, including technological, constructive solutions, which are the essence of information technology.

"Exit" is a solution obtained as the result of the application of an innovative method, innovative technology in combination with the nature of the changed situation.

The research has allowed a classification for the technological processes (models) which is represented in figure 4.

![Figure 4. Classification for the technological processes (models)](image)

4. Conclusion

The following main results were obtained in accordance with the problems:

- comparative analysis was carried out with respect to two types of microclimate control systems: fully and partially automated with an assessment of their advantages and disadvantages;

- goals and technical means of inventions have made it possible to perform the main technological processes in protected ground conditions using partial automation;
- studies have allowed presenting and substantiating the classification of models (processes) for the research of microclimate parameters in various test conditions.

Thus, it has been proven that the application of an automated microclimate control system is a perspective direction for the use of equipment in protected ground conditions. It will reduce the cost and maintenance of the greenhouses themselves in the conditions of the personal plot, as well as simplify its operation.

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