Information coordination of biological and technical objects in the vegetation chamber

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Abstract. The central problem of the use of LEDs in greenhouse production is the establishment of a causal relationship between the environment in a parametric microclimate and the manifested properties of a biological object (phenomenological, biological, spectral sensitivity). Information management systems with biofeedback relate to biotechnical systems in which a biological object directly participates in the formation of control decisions in real time. At the same time, the plant as a biological object detects a feedback channel from the source, which indicates the external plant characteristics (phenomenological and spectral characteristics, intensity of such processes as photosynthesis, respiration, transpiration, etc.).

1. Introduction
Nowadays, it is necessary to recognize the fact that in studies involving plants and LEDs, the traditional empirical search method is used. The effectiveness of this approach is found in the absence of a clear understanding of the patterns of interaction of optical radiation with a biological object. This circumstance is well illustrated in the analytical study [3], which was carried out in the analysis of about 100 scientific sources. The central problem of using LEDs in greenhouse production is to determine the causal relationship between the environment in a parametric microclimate and the manifested properties of a biological object (phenomenological, biological, spectral sensitivity, etc.). Currently, the solution of this problem is impossible without the involvement of information technologies, computer technology and mathematical modeling methods, since they make it possible to abandon the traditional method of empirical search for a biological object with specified properties through experiments that are multifactorial, lengthy and expensive. As a result, for each output (dependent) empirical model variable, a fairly simple functional (most often, approximation) dependence of it on the input (conditionally independent) process variables is obtained. The type and coefficients of these dependencies, as a rule, are determined by the methods of regression and correlation analysis based on the results of data processing of passive or active experiments. The disadvantages of such models, in addition to the need for a large number of refinement experiments, also include the fact that, strictly speaking, they are valid only in the range of variation of the parameters of the technological process in which experimental studies were conducted.

The central problem of using LEDs in the process of growing plants in an artificial microclimate is the problem of predicting changes in a biological object under the influence of certain factors. This issue can’t be resolved by traditional methods, repeatedly tested in the natural sciences, since the integration
into one system of technical subsystems of the microclimate with a biological object has many specific features. Modern achievements in the field of computer simulation of technological processes make it possible to more strictly and more accurately solve the problems of designing and managing microclimate systems for greenhouse production. At the same time, system analysis methodologies are widely used with the application, which successfully solves the problem of analyzing optimization and synthesis of new and reconstructed solutions. The optimal best regime and design parameters of the processes calculated in this case form the basis of the technological regulations of production, make it possible to manage them most efficiently and to the greatest extent meet the requirements of energy and resource saving.

There are certain prerequisites for creating information management systems with biofeedback as applied to plants in conditions of artificial microclimate. First of all, these are technologies and technical means that allow, with some accuracy and efficiency, to record the signs of the functional state of plants as a biological object. Such achievements include image recognition systems, phenotyping systems, technologies for reading information of slow fluorescence and biopotentials, gas analyzers and phytospectrometers, and so on. The information system for making decisions on the choice of the optimal artificial microclimate in biotechnological systems is advisable to consider from the standpoint of the laws of irritation of a plant cell: the ability of a living person to respond to external environmental influences by changing its physicochemical and physiological properties.

Information management systems with biofeedback refer to biotechnological systems in which a biological object directly participates in the formation of control decisions in real time. At the same time, the plant as a biological object detects a feedback channel from the source, which is indicative of external plant characteristics (phenomenological and spectral characteristics, intensity of such processes as photosynthesis, respiration, transpiration, etc.). The peculiarity of a plant as a biological object is a hierarchical multidimensional structure, in which local control is unacceptable due to its low efficiency. The division of a plant model, as a biological object, into independent subsystems is impossible without the loss of a sense of functionality, since all the components of a complete system are interconnected and interdependent. It should be noted that the objective function is not specified and may vary depending on the context of the situation, the history of the process, the reachability of the previous goal. At the same time, the biotechnological system must read and identify common procedural components that will ensure the connection of the elements and the objective function.

The mathematical model of the system is represented as a coupling of input actions X, output Y, own parameters V and functional transformation operator F, that is, \( Y = F \{X; V\} \), and its state as a set of features or their derivatives. The problem is that the operator of functional transformation of a biological object is ambiguous, therefore, the problem of decision making becomes more complicated. In this case, the objective function can serve as a backbone since both the connections and the elements of the biological system are not unambiguous and are significantly influenced by the external environment. The complexity of the biotechnical system with feedback is determined not only by the multi-element and complexity of the links, but also by the need to make decisions in choosing alternative formally presented goals.

Thus, the information system can be implemented in a biotechnical system with an adjustable (parametric) microclimate, to conduct scientific research on modeling the relationship between the artificial environment and the properties of a biological object at different vegetative stages of development (seeds, seedlings, seedlings). A vegetation chamber creates a habitat with a finite set of parameters, the value of which at a fixed point in time determines its state.

2. Information biotechnical systems
At present, the process of studying the state of a biological object is not sufficiently developed methodically. In general, the experimental process should be coordinated with the solution of some problems:

At the stage of structuring carried out:
1. Study of factors that form the environment in a parametric microclimate;
2. The definition in the system of the set of functional elements and the interaction between them;
3. Finding the objective function while it should remain unchanged, i.e. independent of the choice of sets of elements and the connections between them.

At the stage of measurability carry out:
1. The selection in a multicomponent system of a multiply connected type of some fundamental parameters that are included in the description of both input and output values;
2. The choice of a system of standards for the identification of measured system parameters, or the creation of databases for comparative analysis of the results obtained;
3. The choice of a set of algorithms for processing measurement information, allowing to carry out the process of metrological analysis and to assess the reliability of the obtained measurement results.

At the stage of controllability, the following is carried out: implementation of an information and biotechnical system with feedback in an experimental setup for organizing a measurement experiment.

Based on the problem described above and the general requirements for a system of experimental studies, an experimental sample was developed. This setup allows one to form approximated spectra of discrete light sources to a modified spectrum of sunlight, to form a spectrum independently for each of the four RGBW channels and to simulate a photoperiod required by biological objects. The unit is equipped with an automated system for maintaining the microclimate in terms of temperature and humidity parameters. The course of experimental research is described below.

Seeds are laid in a substrate of 50 pieces. Observations were carried out at all stages of the development of biological objects. The study took into account substrate moisture, air humidity inside the system, air humidity outside, illumination at seed level, spectrum, photoperiod, substrate temperature, air temperature inside and outside the installation, atmospheric pressure and CO2 concentration inside the installation. Monitoring the results of research was carried out according to the following indicators: the percentage of germination, the full length of the seedling, the length of the root, the length of the stem, the thickness of the stem, the number of leaves and their leaf area, the color of the seedlings.

![Figure 1. Substrate - ST 18/20 foam rubber (Thickness 10mm, density 18 kg. Per 1 cubic meter, hardness 20).](image-url)
Figure 2. The study of the degradation of a biological object in the absence of substrate and feed fluid.

Figure 3. Measurements of seedlings at the final stage of research.

Figure 4. Conducting research to identify the parameters of biological objects with different spectral indicators of illumination.

According to the results of the work carried out by a team of developers, a patent “3” was issued which is the basis for the design solution. The developed facility is intended for conducting experimental studies on the subject:
- Determination of the optimal parameters of the process of exposure to an alternating light field on the process of stimulating seeds and growing plants.
- Determination of the dependence of the parameters of optical energy (intensity, spectrum, duration), the rotational speed of the lower platform, on the biological activity of a bio-object by phenomenological parameters.
- Determination of the dependence of the microclimate parameters (temperature, humidity, gas composition, composition of the nutrient solution) on the characteristics of the light field on the biological activity of the bio-object.
- Determination of the dependence of the output parameters of the plant’s habitat (temperature, humidity, CO2 gas composition, change in electrical conductivity and acidity in the nutrient solution) on the input parameters of the microclimate (set by the control system).
- Establishing the dependence of the formation of phytocenosis on the parameters of the artificial environment of the plant.
- The climate control system works through the parameters of the habitat of a biological object on the basis of sensory maps of the environment with further comparison of the obtained data and processing them.

3. Conclusion

The developed experimental model became the second stage of the research work, after testing the layout of this system. Laboratory tests have shown that the device has a positive effect on seeds under certain phytostimulation algorithms, significantly improving not only their germination, but also the organic characteristics of the sprouts. The algorithms themselves are still at the research stage, since a large database is required to form chains of dependencies on the development of biological objects and an automatic system for intensifying seed germination processes. At the moment, the installation sets the parameters of the temperature, humidity environment, multi-spectral lighting and discrete lighting modes that regulate the biological rhythms of the plant to meet the requirements of the research set.

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