Investigation of external signs of energy activity of a whole plant depending on the dose of environmental factors

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Abstract. Information in the scientific literature is, in the future, the basis for the development of a methodology for normalizing the dose of environmental factors with an assessment of the energy activity of a plant organism. The experience and prospects of using databases for the analysis of natural and artificial factors of the environment in relation to closed systems with an artificial microclimate are discussed. The growing understanding of the ineffectiveness of the empirical approach to the formation of an artificial microclimate makes it necessary to consider the issue from the point of view of dose dependence and biological effect. The purpose of the study is to create an electronic database "Investigation of signs of plant energy activity on the dose of environmental factors", on which the methodology for standardizing the artificial microclimate in greenhouses will be based.

1. Introduction

We are currently witnessing an intensive rising in the volume of information on the Internet. Systematization of scientific data, like experiment and theory, is becoming a new independent direction of knowledge. The task of systematization is to find information resources of a large volume, different in subject matter, but related to one object of research. The systematization of knowledge was carried out by studying the external signs of the energetic activity of a whole plant for doses of environmental factors. The analytical research was done according to the analysis of scientific articles published in the abstract databases Web of Science, Scopus and eLibrary.Ru (VAK). The search was carried out for the following keywords: plant organism (seeds, plants); environmental factors; factor dose; irritability; stress; adaptation; response mechanism; dose dependence; biological effect; external signs of energy (functional) activity.

The purpose of the knowledge systematization: to detect the presence or absence of links between the scientific knowledge arrays in the studied area which prevent to create the regulation methodology of artificial microclimate in greenhouses.

At present, greenhouse production, as a system of artificial microclimate, is one of the most debated world trends. The flow of information, as an indicator of great interest, has established an indisputable fact that everyone reckons with: in greenhouse production, good results are achieved through a long empirical method of "trials and errors". New crops, technical equipment and complex automated technological processes go through complex approbation. Greenhouse production requires: a high level of knowledge in various fields, a long time for experiments with biological objects and enormous financial costs. Understanding the processes that occur in closed systems of artificial microclimate increases the prediction of results and reduces non-production costs.
Figure 1. Scientific knowledge that should become the basis for creating a methodology for standardizing artificial microclimate in greenhouses

2. Current state of the problem

Plant organisms are closely related to their habitat. Seeds require certain environmental conditions in order to emerge from dormancy. Metabolic processes in a plant have a pronounced dependence on the daily dynamics of the habitat parameters. Thus, the habitat is the source of many signals that are information for plants. The information determines the strategy of plant growth and development. Information represents a certain amount and quality of energy (thermal, electromagnetic) or substance (water, fertilizer, gas). Plants show plasticity to this kind of information. Search, collection, storage, analysis, application of signals from the habitat, as a special type of "information for plants", is an important scientific and practical problem.

Habitat factors are of a different nature. Environmental factors can be conditionally divided into biological, physical, chemical (Vartapetyan B.B., Pimenov M.G.). Environmental factors have two
effects on the plant organism: damaging and irritating (stimulating) (Urmantsev Yu.A., Gudskov N.L.). Irritability (excitability) is a property of a cell, tissue and organ to respond by changing the structures and functions of intracellular formations. Plant stress is described as a change in successive states: initial destabilization of functions (irritability), normalization of the biological system (adaptive activity), and transition to a new structural and functional state (either increased resistance, or serious damage and death) (Selye, H.; Larcher W.).

Adaptation mechanisms were formed in a long process of evolution, so their number is optimized by a small number (Veselova T.V., Veselovsky V.A., Chernavsky D.S.). Plants react to physical (chemical) factors that do not occur in nature, and exhibit a response similar to natural stress (Batygin N.F.). The physiology of living organisms provides typical universal answers: the universality of the genetic code, the structure of membranes, and more. The universal properties of biological objects are a consequence of the evolutionary unity of living things. Biological organisms implement responses that are carried out in stages and include a cascade of events that occur at the molecular, cellular, tissue, organ, organismal and population levels [1]. Functional and structural changes at the molecular level cause changes in the growth, development, resistance, viability and productivity of plants (Polevoy V.V., Salamatova T.S., Tarchevsky I.A.). It is possible to use abiotic and biotic factors in certain doses to control the growth, resistance and production process in plants.

Systems with an artificial microclimate have the ability to control the parameters of environmental factors especially for the plant organism. Natural environmental factors are temperature, humidity, light, gas composition and nutrient solution. Artificial factors affect to the spectrum of physiological processes, activate of growth, changes in the physicochemical state of the cell, activate of energy and plastic metabolism, the appearance of morphoses and more (Khrustaleva L.I.). The mechanism of the plant organism's response to artificial influences is of great interest and a large body of knowledge: ultrasound [2], laser light [3,4], electric and magnetic fields [5,6], ionizing radiation [7,8], low and high temperatures [9], ionized and magnetically activated water [10,11], pulse pressure [1], ultraviolet radiation [12,13], infrared radiation [14], LED visible radiation [15], dynamic lighting [16,17] and other.

Numerous studies show that the action of small doses can lead to the stimulation of physiological processes in plants [18]. Weak influences induce a plant response and trigger a response that is aimed at increasing productivity [19]. Judging by the number of scientific projects, a huge amount of knowledge is concentrated in this area, which is difficult to use due to the complexity of the biological object.

An external sign of the functioning of systems could be a criterion for the stress of a biological object. The search for such criteria is an important scientific and practical problem [20]. Fundamental knowledge of the reasons that increase the productivity of plants should lead to the creation of a model of the response of a whole plant to certain doses of environmental factors [21,22,23].

External signs of the energy (functional) activity of biological organisms are practically not studied. They do not have a common scientific concept and exist in the scientific literature as independent phenomena (phenomena) in the process of studying plant physiology: bioelectropotential [24,25,26]; slow induction of fluorescence of photosynthetic objects [27]; thermo-luminescence of plants [28]; rhythms of sol-gel transitions in living cells (Zaguskin S.L.); gas-discharge visualization (Kirlian effect); acoustic response from a biological organism (seeds) [29]; visual phenotyping [30]; computer microtomography [31]; laser photometry and spectroscopy [32]; magnetic resonance microtomography [33]; multispectral visualization [34]; X-ray method (Musaev F.B.-O., Bondareva L.L., Antoshkina M.S.); and other.

There is a real body of knowledge with unique methods, but at the same time there are no express tests for assessing the genotypes of organisms in terms of productivity and resistance to environmental factors. Express diagnostics, which could combine environmental factors with the identification of external signs of energy activity of biological organisms, could give impetus to the creation of a methodology for standardizing artificial microclimate in greenhouses.
Thus, an analytical study on the systematization of knowledge showed the presence of large arrays of accumulated knowledge in two areas: study of the mechanism of plant response under the influence of various artificial environmental factors; and research of external signs of energy (functional) activity of plants.

3. Experience and methodology for building databases

The modern concept of sustainable development and optimization of the technological process in greenhouse production involves the accumulation of information about innovative technologies, equipment, methods of monitoring and diagnostics of technical systems and a biological object. To accomplish this task at the modern level, information technologies and computer data processing tools, database management systems, knowledge bases, information and reference and expert systems, etc. are increasingly being used.

Examples of this kind of Databases are: identification of biological species for studying and forecasting biodiversity [35]. There are databases in the Botanical Garden of Moscow State University [36], at the Institute of Forest named after V.N. Sukachev, the Institute of the Siberian Branch of the Russian Agricultural Academy is developing the Database of Grain Crops.

World experience is the example of the creation of the European Radiobiological Archive (ERA), which was later combined with similar Japanese and American data repositories [37]. Currently, the ERA contains information on almost all studies from the 1950s to the 1990s, which is unique information [38,39].

It should be noted that at present, in the context of the global growth of the volume of information, it is advisable to develop methods and tools for extracting knowledge from large data arrays. Empirical observations, scientific research, processing of experimental results lead to the accumulation of arrays of numerical and functional characteristics of significant dimensions, which complicates the storage, analysis and interpretation of the results obtained. At the same time, the sample size can reach enormous sizes, and it becomes difficult to operate with them. The problem of knowledge extraction is an integral part of knowledge engineering (the field of information technology, which deals with solving the problem of converting knowledge into an object of processing within the framework of digitalization of agriculture) [40].

The Database "Biological effect of environmental factors on plants in an artificial microclimate" operates under the control of the Microsoft Access DBMS and is compatible with versions of Access 2000, 2003 and 2007. The Database may be available to a wide range of users, but it is possible that it will be considered in the future prospects for its commercial use with the possibility of placing it on the Internet. The information is contained in five main, related tables: list of literals; original plant organism (seed or plant, crop, variety); dose dependence of the limiting factor; background parameters of artificial microclimate; external biological effect. The Database also includes a set of auxiliary tables for automatic input of information (names of scientific journals, names of plant species in Russian and Latin, characteristics of environmental factors, etc.).

The search for scientific sources was carried out by a continuous method, by keywords, and by a cascade method, in which the cited literature was analyzed. Currently, about 380 publications have suitable materials for entering into the Database, according to preliminary estimates. Note that a significant part of the published works are not suitable for entering into the Database. We reject numerous articles that lack quantitative information on dose dependences (only graphs or a qualitative description of the results are provided). For example, the table "External biological effect" consists of several fields and contains information: about the conditions of the experiments; object of study; type of closed system, parameter of the limiting factor.

Note that the analysis of information obtained from different sources on the effect of environmental factors on a biological organism runs into a number of limitations and contradictions. The response of a living system to a complex of factors is recorded at different levels of organization, from molecular-cellular to coenotic, and depends on both the physical characteristics of radiation (dose and dose rate, quality, duration) and factors of a biological nature that determine the stability and adaptability of the
organism. Each of the experimental works has its own set of these factors, which can complicate the joint analysis of data, and the abundance of sources of uncertainty can lead to insufficient statistical support of conclusions. One of the most serious obstacles is the inhomogeneity and insufficient information of the limiting factor in specific research conditions.

Thus, it is necessary to introduce meta-analysis, which is a method of joint analysis of the results of a large number of independently conducted, often contradictory studies devoted to the study of a common problem [41]. The main difference between meta-analysis and the usual descriptive review is the possibility of obtaining statistically sound conclusions. The meta-analysis strategy is especially suitable in cases where the results of individual studies conflict with each other, the size of the individual studies is too small and the organization of large studies is too expensive [42].

A system of reference objects is needed for this kind of Databases [43]. A reference (conditional) biological organism is a hypothetical object that has certain basic characteristics of a certain type, described according to the taxonomic level "family", with certain anatomical, physiological and behavioral characteristics. For each reference species, it is proposed to accumulate data, taking into account information for a biological organism with similar data, and to develop appropriate models for constructing the dose-effect relationship for a limited set of indicators, which are further supposed to be used for standardization purposes.

4. Prospects for using databases

Fundamental knowledge about plant organisms is becoming more true, thanks to research into the mechanisms of irritability, stress and adaptation of biological organisms (seeds and plants). Knowledge serves as the basis for the creation of innovative agricultural technologies. Fundamental knowledge of the reasons that increase the productivity of plants should lead to the model creation of the whole plant response to certain doses of environmental factors. Adaptation mechanisms were formed in a long process of evolution. Functional and structural changes under the influence of stress cause changes in the growth, development, resistance, viability and productivity of plants. It is possible to use abiotic and biotic factors in certain doses to control the growth, resistance and production process in plants. Plants have systems that realize the reception and analysis of signals, and then the transition of the whole plant to a state of stress. An external sign of the biological systems functioning could be a criterion for the stress of a biological object. The search for such criteria is an important scientific and practical problem.

The main goal of generalization and preservation of information, as shown by numerous studies, is a source of new knowledge. The use of modern approaches will make it possible to conduct a retrospective analysis of previous data, use the data to test hypotheses that have arisen at the current level of development of science. The initiative to create such an Internet resource will provide an opportunity not only to access the Database, but also to expand it by adding new data, reference information, cross-references and the possibility of communication between specialists.

A brief review of scientific Database "Biological effect of environmental factors on plants in an artificial microclimate" allows to outline the prospects for further development of research and development in the field of methodology for standardizing artificial microclimate in greenhouses. First of all, one should accumulate and systematize as much information as possible, conduct its critical analysis, expand the range of analyzed effects, and consider various components of the artificial microclimate.

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