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COPNCEPT OF LOW COST COMPUTERIZED MEASURING SYSTEM FOR MICROCLIMATE PARAMETERS OF GREENHOUSES

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Abstract

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Based on the analysis of topical regulated requirements for modes of cultivation on protected grounds and existing methods and means relating to building computerized measuring devices and systems of microclimate parameters of greenhouses, informative set of physical microclimate parameters of industrial greenhouses was found. The investigated system was developed for both types of greenhouses – heated and unheated. Block diagram of a computerized measuring device was developed using modern low cost component base and technology. Basic functions that are binding in the development of the information-measuring system of microclimate parameters of greenhouses have been listed and substantiated. Operation algorithms and hardware provision of the model meter sample have been designed. The algorithm of integral assessment of the current state of greenhouse microclimate by on-line measurement of regulated parameters with further accumulation of database and building on their basis extrapolation models of informative indicators of dynamics. The priority perspective areas for further research on computerized meters in order to improve efficiency and productivity of agricultural enterprises with protected grounds have been determined.

Key words: computerized measuring system; industrial greenhouse; block diagram; microclimate; functional support; index of physical condition

List of abbreviations: AP – analog processing, E.M.F. – electric motive force, ADC – analog to digital conversion, PDPOS – primary digital processing of output signals, FSDSP – the first level of secondary digital signal processing, SSDSP – the second level of secondary digital processing, MC – measuring channel, PAR – photosynthetic active radiation, IPC – index of physical condition

Introduction

The increase of anthropogenic impact on natural objects and reduction of natural landscapes brings up the issue of conservation, restoration and increasing agricultural diversity under conditions of artificial ecosystems. Thus, methods and tools for computerized measurement using modern low cost technologies are compulsory components for efficiency improving and stimulating the pace of development of agricultural enterprises with protected grounds. Taking into account the current circumstances, research of influence of microclimate parameters on pace and quality indicators greenhouse crops has become a vitally important issue, which enables to develop a scientific approach to agricultural practices of caring for flora and, consequently, improving yielding capacity of industrial greenhouses. Existing methods and means of measuring informative parameters of microclimate do not provide a sufficient level of metrological measurements performance in production environment of greenhouses, and do not allow obtaining comprehensive and extrapolated information on the dynamics of physical parameters of aerogas environment and greenhouse soils, as well as irrigation water quality.

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The aim of the article is to substantiate basic functional provision, to design and research structure and function algorithms of the computerized measuring system of complex of parameters of industrial greenhouse microclimate using modern low cost microprocessor technologies, which will enable to conduct research in order to improve the efficiency and productivity of heated and unheated greenhouses.

Materials and Methods

The paper has solved essential scientific and applied problems of justifying basic functions and designing the structure of the low cost computerized measuring meter of microclimate of industrial greenhouses, which is different from existing solutions by implementation of measurement of the complete list of regulated parameters with necessary metrological characteristics and the possibility of remote registration and processing.

The research methods based on the modern achievements of theory of information-measuring systems; theories of physical and mathematical modeling using specialized software: Mathcad, Microsoft Excel, Arduino IDE; stochastic processes; mathematical statistics; concepts electrophysical and electrochemical analysis of multiphase dispersed media and in experimental research methods multichannel model standards for measuring physical parameters greenhouse microclimate.

It was used specialized hardware for the physical modeling of the computerized measuring system, which is compatible with the Arduino microprocessor platform.

Based on the analysis of a priori information on greenhouse microclimate parameters, most of which depend on the performance of growing crops on protected grounds, we justified the set of greenhouse microclimate parameters that are subjected to immediate computerized measuring (see Table 1). Thus, all studies were carried out for the stated set of microclimate parameters.

Results of the theoretical and experimental research have been obtained into the production process of "F&L" (Ukraine) and "Avdiivka Coke Plant" (Ukraine), as well as in the specialized laboratories State Higher Education Establishment "Donetsk National Technical University" (Ukraine).

Results

Having analyzed modern requirements to principles of crop cultivation on protected grounds (Departmental rules of the technological engineering VNTP APK–19–07, 2007;. Departmental rules of the technological engineering NTP 10-95, 1996; Departmental rules of the technological engineering NTP APK 1.10.09.001-02, 2003), we found that it is compulsive to measure the following parameters in real time operation in the working area of the greenhouses, which are shown in Table 1, which will also enable to use resources and electrical energy more efficiently. Also, a fact of using the computerized system in unheated greenhouses was taken into account in order to expand the air and soil temperature range.

According to the existing information on current locations of agricultural facilities with protected grounds, they are often situated far from their headquarters and specialized laboratories of agricultural enterprises, which deteriorate the rate of prompt response to crop cultivation efficiency. Consequently, the requirement to implement the remote control of greenhouse microclimate is necessary when developing the meter.

Table 1
Set of measurable parameters of the microclimate of industrial vegetable and vegetable seedling greenhouses

Parameter	Measurement range	Permissible measurement error
*Air temperature (t_{air})	4–50°C	Δ_t=±1°C
Air humidity (W_{air})	30–85%	δ_W=±5%
*Soil temperature (t_{soil})	5–45 C	Δ_t=±1°C
Soil moisture (W_{soil})	30–90%	δ_W=±5%
Irrigation water temperature (t_{water})	14–25°C	Δ_t=±1°C
Irrigation water acidity (pH_{water})	5–7 un.	Δ_{pH}=±0.2 un.
Electrical conductivity of irrigation water (σ_{water})	1.5–2.5 mS/cm	δ_σ=±5 %
Concentration CO_2 (C_{CO2})	0.05–0.33 $^{vol.}$%	not specified
Air velocity (V_{air})	0.25–1 m/s	not specified
Level of lighting with regard to physiologically significant zones PAR (E_{wz})	25–300 W/m^2	not specified

* The values are chosen for temperate continental climate zone. The limits are set according to use in unheated greenhouses taking into account the ability of plants to yield

Based on the analysis of specifications and functionality of existing systems for automatic control of greenhouse processes (NPF "Fito", 2016; Promgidroponika, 2016) we found that most of them do not provide on-line measurement of the complete list of regulated parameters and do not provide registration and processing of measurement results. Also drawbacks of known systems include the fact that they do not perform the function of forecasting the dynamics of the measured parameters, which are relevant for inertial objects such as industrial greenhouses and breeding complexes. Existing systems also require significant investment and have long payback period of the project.

So, on the basis of the results of the analysis of prior information, we can conclude that the analyzed computerized meter of greenhouse microclimate parameters must have the following basic functions:

● Function# 1: on-line measurement of microclimate parameters of industrial greenhouses "Inside" and "Outside".

● Function# 2: transfer of measurement data to remote locations of their registration and processing to hotfix informative microclimate parameters.

● Function# 3: formation of a database of measurement results to clarify the existing mathematical models describing the consistent patterns of physical parameters of greenhouse microclimate, and build extrapolation models on their base.

● Function# 4: determination of the current and extrapolated state of the microclimate of greenhouses based on integrated approaches to information processing.

● Function# 5: implementation of the principles of automated and automatic control by means and actuation devices for regulating parameters of technological processes of industrial greenhouses.

The list of required functionalities of computerized control systems of microclimate of industrial greenhouses includes the functionality to create 'adaptive management strategy' (Fito-systems, 2016). This feature involves providing opportunities for an agricultural engineer to use hardware and software control of priority issues of resource and energy saving or maintaining the best possible technology of growing crops, depending on the growth phase of specific types of plants and/or economic feasibility of the project.

One of the advanced features of the computerized measuring device is the ability to remotely configure and administer the system using network technology.

Based on the analysis of mandatory functional and algorithmic support of the investigated computerized meter, we designed a block diagram of the process of measuring information conversion on the complex of specified physical parameters of soils and microclimate of industrial greenhouses, which is shown in Figure 1.

Implementation of the steps of measuring conversion on complex physical parameters of microclimate of industrial greenhouses, which are shown in the form of the block diagram in Figure 1, is as follows:

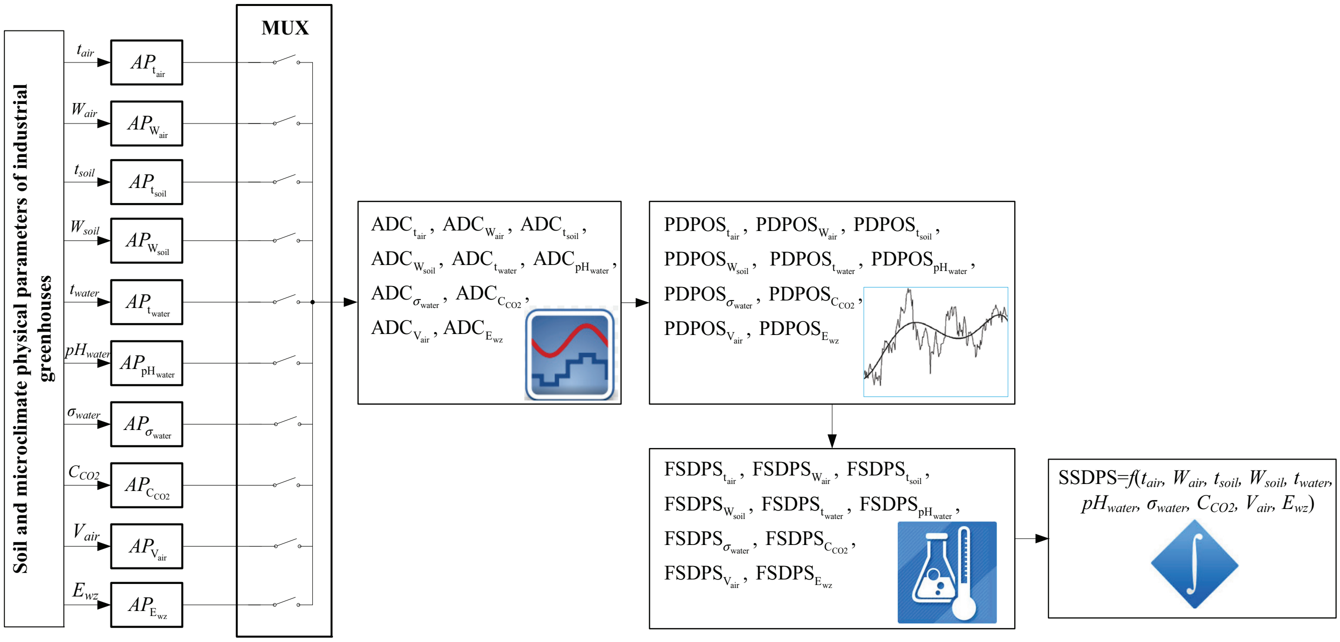

Fig. 1. Block diagram of the process of measuring information conversion on the complex of specified physical parameters

1. Gaining primary measurement information in an analog form from sensors.

2. AP of electrical signals, which involves filtering and scaling of output currents and E.M.F. of appropriate sensors.

3. Converting corresponding analog signals into binary code (ADC).

4. PDPOS: time averaging of package code combinations, identifying and reducing impulse noise and so on.

5. FSDSP: calculating the values of digital signals in units of physical quantities to be measured; calculating the corrections of the measurement results and functional value correction of measured parameters of soil and microclimate of industrial greenhouses based on algorithms developed by the authors (Laktionov, 2015).

6. SSDSP: determining the current and predicted (using extrapolation methods of measurement data) integral state of greenhouse microclimate based on integrated approaches of processing measuring information.

Based on the research done, taking into account the regulated requirements to the set of measurable parameters and basic functional provision for the developed measuring meter of physical and chemical characteristics of industrial greenhouse microclimate, we substantiated the block diagram, which is shown in Figure 2.

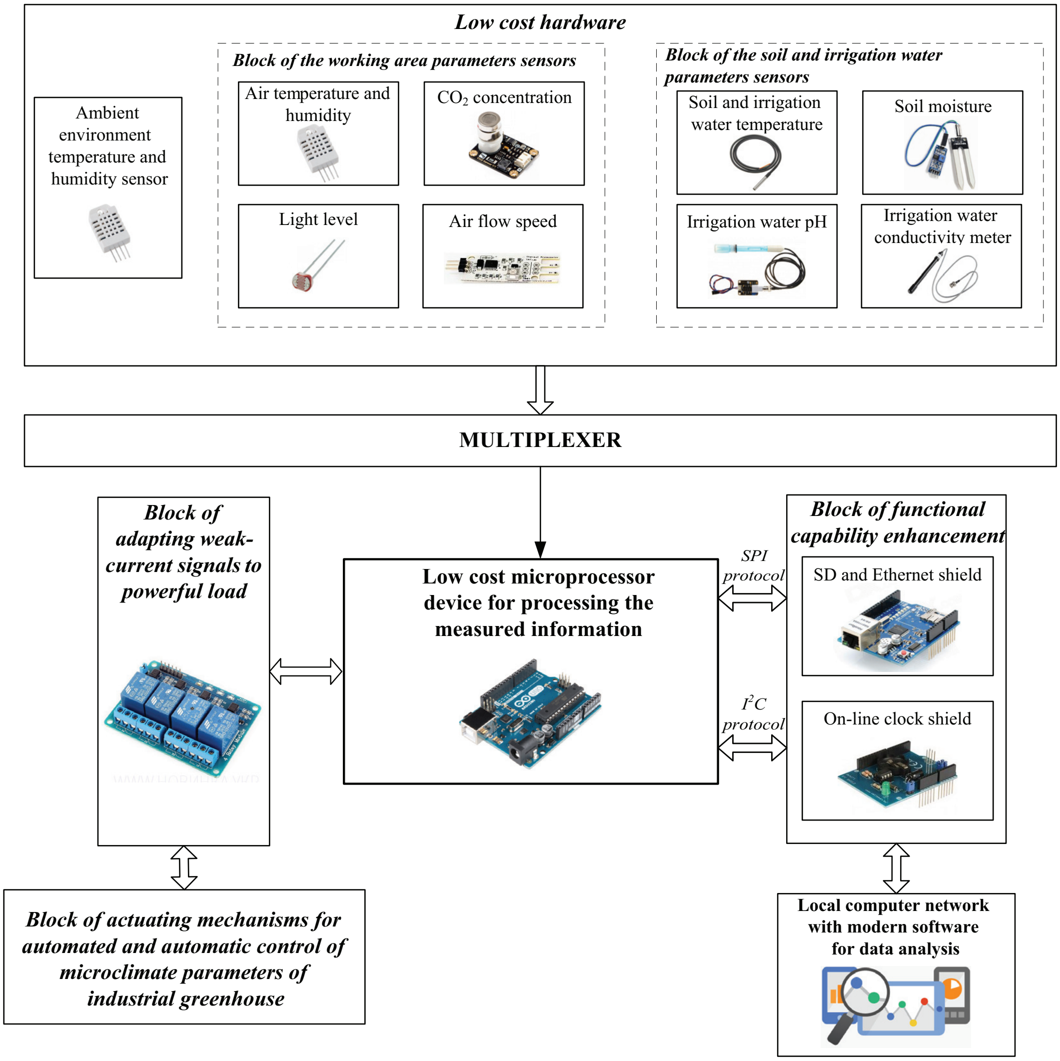

Fig. 2. Block diagram of computerized measuring meter of physical and chemical characteristics of industrial greenhouse microclimate using low cost microprocessor technologies

The principle of the developed computerized measuring device, with its block diagram being shown in Figure 2, is the consistent performance of basic system functions (Function #1 – Function #5). On the basis of the requirements to metrological characteristics and basic functions of the meter, taking into account the results of previous studies (Laktionov and Turupalov, 2014; Laktionov and Nikonenko, 2015), we substantiated the component framework for the implementation of the trial model of the studied system. Thus, the hardware component of the model was implemented with the use of these functional units:

– MC of temperature (*T*) and moisture (*W*) of soil and acidity (*pH*), electrical conductivity (σ) and *T* of irrigation water are based on the designed by the authors a model sample of information and measuring system for physical parameters of industrial greenhouse soils using compatible with Arduino sensors (Laktionov, 2015):

- MC of *T* and *H* of air "Inside" and "Outside" is designed based on DHT22 sensor, which has the following metrological characteristics: *T* measurement range from –40 to +80°C, the total absolute error of ±0.5°C; W range from 0 to 100%, the total absolute error of ±2% (Arduino-ua, 2016);
- MC of light level is based on a photoconductive of VT90N2 type (Arduino-ua, 2016);
- MC of CO_2 concentration is based on an electrochemical sensor of MG-811 type (Arduino-ua, 2016);
- MC of air flow speed is built based on Arduino compatible anemometer (Amperka, 2016);
- as a node of functionality expansion unit we used SD Card Shield; Ethernet ENC28J60 Shield and Real time clock module based on DS1307 chip (Arduino-ua, 2016).

Implementation of the mentioned priorities of research of the computerized meter of microclimate parameters of greenhouses will make it possible to improve yield index of domestic agricultural enterprises which use protected grounds. For this purpose a complex agrophysical index is used that characterizes the current state of the greenhouse microclimate in general and enables to substantiate recommendations of higher quality as for methods to care for alien crops (Terleev et al., 2012). Evaluation of soil means calculating the IPC, a geometric mean of ratios of current parameters, which vary over time, to their recommended values:

$$IPC(\tau)=\sqrt[n]{\begin{aligned}&\left(k_{T_{Air}}^{IPC}\cdot\frac{T_{act}^{Air}(\tau)}{T_{rec}^{Air}}\right)\cdot\left(k_{W_{Air}}^{IPC}\cdot\frac{W_{act}^{Air}(\tau)}{W_{rec}^{Air}}\right)\cdot\left(k_{T_{Soil}}^{IPC}\cdot\frac{T_{act}^{Soil}(\tau)}{T_{rec}^{Soil}}\right)\times\\&\times\left(k_{W_{Soil}}^{IPC}\cdot\frac{W_{act}^{Soil}(\tau)}{W_{rec}^{Soil}}\right)\cdot\left(k_{V_{Air}}^{IPC}\cdot\frac{V_{act}^{Air}(\tau)}{V_{rec}^{Air}}\right)\cdot\left(k_{C_{CO2}}^{IPC}\cdot\frac{C_{act}^{CO2}(\tau)}{C_{rec}^{CO2}}\right)\times\\&\times\left(k_{E}^{IPC}\cdot\frac{E_{act}(\tau)}{E_{rec}}\right)\cdot\left(k_{T_{Water}}^{IPC}\cdot\frac{T_{act}^{Water}(\tau)}{T_{rec}^{Water}}\right)\cdot\left(k_{pH_{Water}}^{IPC}\cdot\frac{pH_{act}^{Water}(\tau)}{pH_{rec}^{Water}}\right)\times\\&\times\left(k_{\sigma_{Water}}^{IPC}\cdot\frac{\sigma_{act}^{Water}(\tau)}{\sigma_{rec}^{Water}}\right)\end{aligned}} \quad (1),$$

where *IPC*(τ) is an integral indicator of greenhouse microclimate that changes over time τ:

$T_{act}^{Air}(\tau)$, $W_{act}^{Air}(\tau)$, $T_{act}^{Soil}(\tau)$, $W_{act}^{Soil}(\tau)$, $V_{act}^{Air}(\tau)$, $C_{act}^{CO2}(\tau)$, $E_{act}(\tau)$, $T_{act}^{Water}(\tau)$, $pH_{act}^{Water}(\tau)$, $\sigma_{act}^{Water}(\tau)$ are current values of measured physical parameters of greenhouse microclimate:

T_{rec}^{Air}, W_{rec}^{Air}, T_{rec}^{Soil}, W_{rec}^{Soil}, V_{rec}^{Air}, C_{rec}^{CO2}, E_{rec}, T_{rec}^{Water}, pH_{rec}^{Water}, σ_{rec}^{Water}

are recommended, according to (Departmental rules of the technological engineering, NTP APK–19–07 (2007); Departmental rules of the technological engineering NTP 10-95 (1996); Departmental rules of the technological engineering NTP APK 1.10.09.001-02 (2003)) physical parameters of industrial greenhouse microclimate, which are equal to average values of growing period and depend on plants types and vegetation periods:

$k_{T_{Air}}^{IPC}$, $k_{W_{Air}}^{IPC}$, $k_{T_{Soil}}^{IPC}$, $k_{W_{Soil}}^{IPC}$, $k_{V_{Air}}^{IPC}$, $k_{C_{CO2}}^{IPC}$, k_{E}^{IPC}, $k_{T_{Water}}^{IPC}$, $k_{pH_{Water}}^{IPC}$, $k_{\sigma_{Water}}^{IPC}$

are weights of measured parameters, approximate relative values are 14%, 11%, 12%, 10%, 5%, 7%, 14%, 10%, 10%, 7% – approximate values are shown for a cucumber based on an analysis of the results in source (Theoretical substantiation of methods for increasing the cucumber yield in greenhouses, 1995), total value must be equal to 100% ; *n* – number of measured parameters.

The proposed index of assessment of integrated state of industrial greenhouse microclimate (Amperka, 2016) enables to implement the algorithm of calculating IPC in the microprocessor unit of the developed computerized meter which enables to quickly analyze the averaged information on: temperature and humidity; CO_2 concentration and light level of the greenhouse working area; temperature and soil moisture; acidity, temperature and conductivity of irrigation water; the speed of air flow in time within operating ranges of changes in the mentioned parameters for timely and objective justification of farming techniques to increase yields of agricultural enterprises on protected grounds.

Discussion

In view of the above said, we can conclude that the implementation of the model meter based on the block diagram, which is shown in Figure 2, will make it possible to use it as a tool for further research in the following priority areas: identification of consistent patterns of mutual influence of measured parameters on common metrological characteristics of the computerized meter and performance of growing plants on protected grounds; development of programs and methods of multifactor laboratory testing of the model computerized meter of microclimate parameters of heated and unheated greenhouses; making physical models of the meter of microclimate parameters of greenhouses; improving existing and creating new mathematical models of processes occurring in measuring channels of the computerized meter of microclimate parameters of greenhouses; making models of forecasting the dynamics of informative parameters of microclimate of greenhouses considering destabilizing factors; development of methods and means of automatic control of technological processes of growing alien crops on protected grounds.

Implementation of the mentioned priorities of research of the computerized meter of microclimate parameters of greenhouses will make it possible to improve yield index of domestic agricultural enterprises which use protected grounds.

Conclusions

Structural organization of the low cost computerized measuring device for microclimate parameters of industrial heated and unheated greenhouses has been investigated based on study and synthesis of its subsystems functional maintenance. It provides comprehensive temperature and humidity; concentration of CO_2; the level of light in terms of natural PAR; temperature and soil moisture; acidity, temperature and conductivity of irrigation water; speed of air flow measurements.

The functional software of the designed meter has been justified, which allows to perform complex computerized measuring the complex of physical parameters of soils and greenhouse microclimate with the possibility of remote recording and processing information that meets the regulated requirements of relevant regulatory documentation on regimes of growing vegetables on protected grounds with the capability to assess the current and predicted values of integral state of microclimate greenhouses for growing vegetables.

The main priorities for further scientific and applied research on improving cultivation process on protected grounds by developing a microprocessor network meter of measuring microclimate parameters of greenhouses.

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References

Amperka, 2016. http://amperka.ru/product/anemometer (Accessed 22.04.2016)

Arduino-ua, 2016. https://arduino-ua.com/cat6-Datchiki (Accessed 20.04.2016)

Departmental rules of the technological engineering NTP 10-95, 1996. Norms of technological designing greenhouses and greenhouse combines for growing vegetables and sprouts. *Gipronisel-prom*, Moscow, 87 pp. (Ru).

Departmental rules of the technological engineering NTP APK 1.10.09.001-02, 2003. Norms of technological designing breeding complexes and reproduction greenhouses. *Giproniselprom,* Moscow, 24 pp. (Ru).

Departmental rules of the technological engineering VNTP APK–19–07, 2007. Greenhouse and greenhouse businesses. Structures protected ground for farming (rural) farm. *HIK*, Kiev, 140 pp. (Ukr).

Fito-systems, 2016. http://www.fito-system.ru/upravlenie-mikroklimatom-teplicy (Accessed 16.04.2016)

Laktionov, I. S., 2015. The computerized information-measuring system of the industrial greenhouses soil physical parameters with destabilizing influences compensation: abstract of the dissertation for the Ph.D. degree. *DonNTU*, Krasnoarmeysk, 20 pp. (Ukr).

Laktionov, I. S. and M. Ju. Nikonenko, 2015. Field meter of the soil acidity with hardware and software compensation of the natural moisture destabilizing effect. Scientific works of Donetsk National Technical University. Series: computer science and automation, 1 (28): 133-140 (Ukr).

Laktionov, I. S. and V. V. Turupalov, 2014. Development and research of the soil moisture meter model sample. Scientific works collection of Donetsk Railway Transport Institute of Ukrainian Railway Transport State Academy, 38: 13-19 (Ru).

NPF "Fito", 2016. http://www.greenhouses.ru/Kontrol-za-tehnicheskimi-parametrami-v-teplicah (Accessed15.04.2016)

Promgidroponika, 2016. http://www.promgidroponica.ru/index.php=node/1198 (Accessed 15.04.2016)

Terleev, V. V., R. A. Polouektov and B. I. Bakalenko, 2012. The structure of the information providing a model for the agricultural structures production process. *Agrophysics. St. Petersburg Agrophysical Research Institute,* 2 (6): 29-36 (Ru).

Theoretical substantiation of methods for increasing the cucumber yield in greenhouses, 1995. http://earthpapers.net/preview/471381/a?#?page=14 (viewed, 14 August 2016)