Application of electrical technologies to increase the productivity of cucumber in protected ground structures

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Abstract. The rationale for the need to improve greenhouse complexes using energy-saving technologies for growing vegetable products, including cucumber, is presented. The purpose of the work is to justify the use of modern electrical technologies in protected ground structures to increase the productivity of cucumber. Based on the objectives of the study, the following tasks were identified: analysis of the operating modes of electrical equipment to identify ways to increase its productivity and reduce energy costs in the production of cucumbers on protected lands, significantly increase the efficiency of pre-sowing treatment of cucumber seeds by developing a system for automatic stabilization of the ultraviolet radiation dose. Energy requirements are related to the strategic choice of producers in relation to the structure, greenhouse and climate equipment used, such as ventilation systems, cooling, heating, as well as cultivation and adaptation methods. The search for new and efficient electrical technologies is becoming an urgent research aimed at optimizing the entire technological cycle and all stages of obtaining a high and high-quality crop. Including: 3D light surveillance models affecting the angle of the roof of the greenhouse in the direction, as well as this approach allows the greenhouse to receive 25% more natural light in the winter months, saving up to 15% energy; two new sensors will be tested to measure the true photosynthesis of crops; existing LED lighting has achieved an energy efficiency increase of about 40% in both summer and winter.

1 Introduction

New technologies make it possible to study plants and improve growing conditions, which, in turn, improves the quality of vegetable plants, increases productivity and increases their resistance to diseases, and facilitates the production process itself [10].

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Closed greenhouse ecosystems allow you to get different types of crops.

Greenhouses are considered to be a sustainable production system, using high-tech equipment necessary to control the microclimate and the growth processes of different plant species. It should be noted that technological innovations and ongoing research in the context of obtaining high and environmentally friendly crop yields may not be suitable for use in greenhouse parameters and values, so all types of technological processes are now being adapted to greenhouse conditions [25]. Such a vegetable crop as cucumber is no exception. Determining energy measures suitable for the local climate will increase energy efficiency and crop productivity to achieve the goal of greenhouse sustainability.

Renewable energy efficient control systems are common in modern greenhouses where crops such as cucumbers are grown [23].

Greenhouses, in comparison with open areas, territories, intensify the development of agriculture in general, significantly expanding the growing season and, accordingly, the production of crops per square meter of cultivated soil.

However, since annual production is more energy intensive, the significant increase has resulted in a large increase in energy demand. Recently, researchers have shown an increased interest in adapting green energy technologies in greenhouses, which suggests some important ideas for using renewable energy sources to ensure the sustainability of greenhouses in different countries.

The main justification for the use of electrical technologies is that Russia, Uzbekistan in this case is a zone of risky farming. Accordingly, the maintenance of microclimatic parameters in the structures of the protected soil must be strictly controlled, which requires large resource costs. Indeed, greenhouse construction in the field of research is a developing agricultural activity, for which some complications in the greenhouse economy are the cause. One of them is the type of production. The energy efficiency of growing cucumbers can vary greatly, due to the fact that day and night temperatures and their differences occur during the period when the highest yield is achieved, and by reducing the green component from the greenhouse, harmful factors in the greenhouse are maximized.

It is clear that in order to increase energy consumption and obtain highly professional, selective-worked crops. Currently, the introduction of robotic greenhouse technology into existing closed greenhouse structures is gaining popularity. Since this largely ensures the maximum yield of products and the reduction of energy and resource costs.

The development of methods and technologies aimed at high-intensity plant growth, as well as the optimization of factors that determine the integrity of a particular agrobiogeocenosis, will optimize microclimatic conditions.

The most profitable crop for production on soil-optimized equipment is cucumber. Due to the fact that this type of plant is not strongly dependent on natural irradiation, while maintaining the optimal average temperature intensity.

The use of intensive energy-saving electrical technologies in preserving the production of cucumbers is justified. Since most greenhouses have imperfect technologies, suboptimal growing conditions are usually associated with inefficient microclimate and energy control. It has been established that cucumbers greet respond to a complex of external conditions. At the same time, the cultivation of this crop indirectly does not have primary and secondary conditions, since all of them are necessary.

The current technology perspective is to ensure that greenhouse ecosystems remain energy efficient and resource efficient for many years to come. The goal is to maximize efficiency, minimize operating costs and reduce environmental impact.

Currently, research is being carried out in two directions: the overall reduction of energy consumption and the sustainability of greenhouse complexes.

The principles for this are:

1. efficient use of natural sunlight (free energy input to the greenhouse, free light for

crop growth and production);
2. good and optimal thermal insulation (prevention of energy losses through the greenhouse cover);
3. efficient use of energy (eg, new generation cultivation strategies, mechanical dehumidification, ambient light, optimum CO 2 content, low temperature heating, high humidity levels);
4. replacement of fossil fuels with renewable energy sources (for example, geothermal energy, biofuels, solar energy, wind) [9].

Energy savings can be achieved by applying an electro technological solution in the form of using sensors at the time of designing greenhouse systems. Heating energy savings of 80% can be achieved for cucumber crops with an unsupervised greenhouse complex, compared to the average practice in a highly insulated greenhouse.

Another greenhouse ecosystem concept focuses on maximizing the use of natural sunlight at low sun elevations. With 3D ray tracing models, the angle of the greenhouse roof influences the orientation. The influence of the shape and materials of construction, as well as the influence of various diffuse coatings with antireflection coatings and hydrophilic properties of condensation on light transmission in the winter months, is quantified. With the new concept, the greenhouse is expected to receive 25% more natural light during the winter months.

Wireless sensors are used to measure the distribution of temperature and humidity in many places inside the greenhouse. Innovative web-based decision support models have been put into practice to gain insight into climate distribution and predict crop health risks. The microclimate in the greenhouse is automatically adjusted depending on the most humid or coldest place in the greenhouse [11].

Thus, it is possible to save up to 15% of energy and minimize the risk of developing diseases caused by phytopathogenic microorganisms. Two new sensors have been developed to measure the actual photosynthesis of crops and are currently being tested in practice. The sensors are based on the balance of carbon dioxide content and the measurement of the chlorophyll fluorescence intensity of the crop using a laser and photo camera. It is assumed that in the future such information will be directly used for climate control in greenhouses or crop management [6; 15].

The reaction of cucumber crops to additional lighting with high-pressure sodium and LED lamps and their effect on the efficiency of lighting and heating energy was studied. The accumulation of crops in the middle of winter, when there was little sunlight, started slower with LED lighting than with other lighting systems. The power consumption for LED-LED, Sodium-LED and Sodium-Sodium LED is different. The applied LED lighting has increased the efficiency of energy use by about 20% both in summer and winter [9].

It should be noted that the reduction in energy demand is due to the strategic choice of manufacturers in relation to the structure of the greenhouse and climate equipment used, such as ventilation systems, cooling and heating and cultivation methods. For example, keeping transpiration low in winter can have a positive impact on greenhouse energy efficiency, as less water is released into the greenhouse air and less energy is needed to control humidity. The search for new and efficient electrical technologies is becoming an urgent research aimed at optimizing the entire technological cycle and all stages of obtaining a high and high-quality cucumber crop.

The purpose of the work is to justify the use of modern electrical technologies in protected ground structures to increase the productivity of cucumber.

2 Materials and methods

The purpose of the work is to increase the productivity of cucumber through the integrated

use of electrical technologies, the development and application of appropriate control algorithms for automated means of ensuring the microclimate of protected ground structures.

Research objectives: to analyze the operating modes of electrical equipment in the production of cucumber in protected ground to determine ways to increase its productivity and reduce energy costs; significantly increase the efficiency of presowing treatment of cucumber seeds by developing a system for automatic stabilization of the ultraviolet radiation dose, as well as developing a method for calculating the radiation dose during presowing treatment of cucumber seeds, taking into account the influence of their shape factor, based on mathematical modeling of the process; to develop the design of a device for pre-sowing seed treatment, to conduct production tests in protected ground conditions of irradiation plants to confirm the hypothesis of reducing energy consumption while maintaining the quality of the cucumber.

The methodology and research methods are based on a systematic approach to the object of study as an integral set of theoretical and experimental results and consist in the use of mathematical, comparative analysis and monographic observations methods.

Comparison of the main characteristics of modern greenhouses to determine the optimal microclimate parameters for the production of high-quality agricultural products and research. For the formation of sustainable and promising greenhouses, the method of analysis and comparison, evidence-based and practically confirmed data presented in publications [17] was used.

3 Results and discussion

The following conditions for growing cucumber should be indicated. Cucumber (Cucumis sativus L., 1753.) is a common and widely consumed agricultural crop. Being a thermophilic crop, cucumber seeds have been found to germinate at soil temperatures above 12°C. And at a temperature of 17 0C, shoots appear on the seventh day. It should be noted that the temperature optimum for germination in general is 24-30 0C (Table 1).

Table 1. Requirements for growing conditions and characteristics of vegetable crops - cucumber (Cucumis sativus L.) in closed ground

Culture	Characteristic	Rationale
Cucumber (*Cucumis sativus* L.)		
thermophilic	Seed germination occurs at a temperature of +12...+13°C. Germination optimum - +24...+28°C.	Damage to organs or death of the plant - temperatures below +10 °C. Delayed growth and development of plants, reduced intensity of pollen production - air temperature below +15°C.
	The optimum temperature for seedlings is +17...+18°C	The optimum temperature for fruiting - + 24 ... + 30 ° C during the day and over + 16 ° C at night
Short day, photophilous plant.	Use additional lighting	In order to obtain an optimal yield, varieties that are neutral in terms of day length are grown.
Soil moisture demanding	Growth retardation. There is a shift in the sex of the flowers to the male side. There is bitterness in fruits	The optimum relative humidity is 85%. During the growth of the leaf surface - 75%, during the flowering period - 60%.

Source: Compiled by the authors

High temperatures promote the formation of a large number of male flowers. At the same time, a night temperature of 15 ° C is necessary for the formation of female flowers. It has been established that the culture is demanding on air and soil humidity. An increase or decrease in soil moisture by 50% leads to a decrease in yield. Humidity must be at least 80%. Cucumbers need soil rich in humus. The root system requires active gas exchange. Cucumber is demanding on carbon dioxide.

A short review of modern vegetable growing technologies has shown that thanks to new electrotechnological approaches adapted to local conditions, the productivity and sustainability of greenhouse systems is significantly increased. The direction of growing plants in protected ground has a great potential for growth, given the economic growth and high technological level, which makes it possible to obtain high-quality agricultural products [14].

The cultivation of cucumbers, like other fast-growing vegetables, is characterized by technologies aimed at increasing intensive production. Agrotechnical methods are aimed at providing an appropriate root and nutrient medium, balanced growth of roots or leaves, their balanced development, ensures a good level of harvesting of high quality crops. The most important growing methods are microclimate control, maintaining previously established conditions. Cucumber as a crop is very sensitive to both abiotic and biotic stresses, and in case of improper care, it can completely die and nullify the yield.

The search for modern technological solutions made it possible to identify the following areas, justified to increase the productivity of cucumber [13]. Works based on repeated variants of illumination of cucumbers explore the effect of changing optical irradiation. All this allows to reduce energy consumption in the complexes.

Comparing the yield of cucumbers under LED lighting with a combination of LEDs, it was found that using sensors in the substrates can save water even better and optimize plant growth. Refuting the notion that growing in greenhouses is not energy efficient and sustainable. By comparing the growth of cucumbers under different combinations of light, different lighting regimes can be tested. Record all the elements that govern optimal plant growth, including light levels, color spectrum, uniformity of light levels, and light on and off times. As a result, certain colors can be used with LEDs. Having a direct effect on photosynthesis, red and blue colors, while other colors can be added to a certain extent to control other processes of the plant, such as height, assimilation balance (the correct balance of carbohydrates produced by the plant), which undoubtedly contributes to a change in palatability.

Currently, LED lighting is twice as efficient as traditional lighting. A targeted strategy for the supply of water and nutrients to the soil should be developed to improve yields and crop quality. This can be achieved by precisely controlling the moisture content of the substrate, the temperature of the root zone and the electrical conductivity in accordance with the prevailing climatic conditions, the generative and vegetative balance of the plants.

Growers will now have a quick and easy overview of their irrigation strategy on a daily basis. In addition, the toolbar gives a quick view of the state of the plants. This will help you understand if you are moving in the right direction with your chosen growth strategy. New optimized crop management indicators show whether the chosen growing strategy has a neutral, vegetative or generative effect on plant growth. Based on this information, it is possible to direct the crop in the right direction by changing the irrigation strategy accordingly [8; 1].

It is noted that technologies for growing plants in greenhouse ecosystems certainly require the use of highly efficient sources of optical radiation.

It is clear that the supply of new energy-efficient and lighting materials to greenhouse complexes, namely equipment, is an important aspect of the further basic productivity of plants. At the same time, it should be noted that complex theoretical and experimental studies

make it possible to identify the main directions for further improving the efficiency of illumination. Changes in the basic biochemical processes occurring in plants, such as photosynthesis and respiration, undoubtedly depend on the level of illumination. The production of carbohydrates creates flavor in cucumber fruits. This means that lighting material as a technological solution is an important factor in increasing the productivity of cucumbers [2].

It is necessary to justify and present the conditions for growing cucumber. Protected cultivation of cucumber in safe ecosystems (substrate culture, hydroponic) in optimal microclimatic conditions has become an alternative to sustainable vegetable production as a result of changing climatic parameters, including those associated with soil. Year-round cultivation of cucumbers was made possible by the formation of protective structures, making it an economically viable technology for producers.

An integrated approach and co-management of fertility, economic viability and potential benefits are the result of proven energy efficient technologies. It has been established that, of course, temperature is an important parameter for creating an optimal microclimate in greenhouse ecosystems. It is clear that it must be maintained in the required range and due to various variations, as well as by controlling the intensity of different types of heating. The use of energy-saving screens and different types of fans creates an optimum temperature in the greenhouse ecosystem. Coordinated control of microclimatic parameters, performed with the help of sensitive sensors, including biosensors, will make it possible to obtain a high yield in greenhouses of any greenhouse design [12; 3].

These factors led to the formation of the main trend in the development of the greenhouse market, in particular, the reduction in maintenance costs. New energy-intensive technologies are replacing old and costly ones. This is realized by creating, as well as increasing the capacity of a semi-closed type of greenhouses. It is as a result of creating optimal artificial lighting conditions in such greenhouse complexes that energy costs are reduced, namely, due to the design solutions of greenhouses and equipment. Now, the use of highly productive agricultural technologies has created a significant increase in production efficiency through an increase in yield and a decrease in the share of operating costs, including energy and raw materials [7; 8].

Interplanting is one of the advanced technologies in vegetable production that when the plants have grown and the foliage is very large, the light of the upper illumination cannot penetrate the foliage into the growing zone to a sufficient extent. The following can be identified as energy-efficient technologies: circulating irrigation systems with disinfected drainage solutions; horizontal and vertical energy-saving screens, humidification systems and forced air circulation to maintain optimal microclimate parameters [24; 16; 19].

Currently, research is mainly devoted to studying the effect of solar radiation on the productivity of various biological objects that are grown in artificial closed agroecosystems. This is not accidental, as the demand for high-quality crop products has increased significantly [20]. It is the change in humidity, temperature, as well as the content of carbon dioxide in the earth's atmosphere under the influence of photosynthetically active radiation and natural solar radiation [21, 26]. Photosynthesis and its management is the most important indicator of the quality seedlings created by any culture [22, 27]. Research and analysis of experimental data on the direct relationship between solar radiation, temperature and humidity in protected ground has not yet been established [5, 28]. For example, the response of cucumber crops to additional lighting with high-pressure sodium and LED lamps and their impact on the efficiency of lighting and heating energy use was studied.

The LED lighting used increases energy efficiency by about 40% both in summer and winter. However, due to the fact that the low heat output from pure LED lighting in winter was compensated by the largest amount of heat, which is aimed at the development of fruits. At the same time, the yield remained low in the middle of winter, and the heating per unit of

crop when using light-emitting diodes was high [18].

4 Conclusion

In general, comparing the data obtained and making an analysis, it was found that the main electrical technologies used in growing cucumbers in greenhouse ecosystems are different types of high-tech equipment for controlling the microclimate in greenhouses.

Redesigning greenhouses in local climates for better indoor climate control and energy efficiency are the most important issues in growing quality vegetable products. The importance of using potential renewable energy systems (ie geothermal, solar and wind) in the design of a greenhouse energy profile that modifies microclimatic conditions to optimize output per unit of energy has been established.

Increasing energy efficiency is in line with current environmental concerns and the goal of reducing carbon dioxide emissions from greenhouse production. Thus, as a result, it is necessary to designate the basic functions of ensuring the vital activity of greenhouse agroecosystems through electrical automation. In this case, these are the regulation and management of irrigation, maintaining the desired temperature of the soil and water, the air in the room, controlling the carbon dioxide content in the air, maintaining the optimum humidity of the air and soil, and the level of illumination. All this is done with the help of sensors and there is a promising improvement.

Protected cultivation of cucumber in protected systems (substrate culture, hydroponic, etc.) under optimal working microclimatic conditions has become an alternative to sustainable vegetable production as a result of changing microclimatic parameters. The introduction of electrical technology of variable optical irradiation into industrial greenhouse complexes is a promising method and a modern approach to obtaining high yields of cucumber crops.

It is recommended to study the potential of applying in other crops in the Republic of Uzbekistan algorithms developed automatic dose stabilization systems for irradiation of seeds and seedlings of vegetable crops and the program of regulation of microclimate parameters in protected soil structures.

The results of the study are mainly focused on the cultivation of cucumbers in protected areas in Tashkent, Fergana, Namangan and Andijan regions, and in the future it is recommended to test the availability of technology and equipment designed for outdoor and other types of vegetable crops.

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