Method for increasing the efficiency of growing environmentally friendly crops

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Abstract. The article considers a way to increase the efficiency of growing crops. The influence of visible light spectra on the development of plant parts during the vegetative period has been revealed. The correlation table reflecting mutual influence of plant parts under exposure to visible light spectra has been compiled. The method of irrigation water polarization to increase its biological activity is considered. A complex method aimed at intensification of plant growth in a physical way, which can improve the productivity of production, is proposed.

1. Introduction

The Decree of the President of the Russian Federation of January 21, 2020 № 20 "On the approval of the Doctrine of Food Security of the Russian Federation" [1] declared the national interests in the sphere of food security, one of which is the creation of a highly productive sector in agriculture, developing on the basis of modern technologies. At the same time, the main directions of state policy in the sphere of food security were the creation of new technologies for the production, processing and storage of agricultural products, raw materials and food that meet the established environmental, sanitary and epidemiological, veterinary and other requirements, in order to provide the population with quality and safe food products, their implementation and use, as well as the development and implementation of technical and technological modernization programs, including the introduction of new equipment and technologies that increase labor productivity, energy efficiency, resource conservation and loss reduction in agriculture and fisheries [1].

The latest edition of The State of Food Security and Nutrition 2020 estimates that nearly 690 million people worldwide are hungry in 2019 - 10 million more than in 2018 and nearly 60 million more than five years ago. In addition, billions of people cannot afford healthy and nutritious food because of its high cost and low affordability. Asia has the largest number of hungry people, but Africa has seen the fastest increase.

While the world's population is hungry, it is problematic to provide the necessary food growth. According to preliminary estimates, an additional 593 million hectares of agricultural land will be required by 2050, compared to 2010 levels, which is almost twice the area of India [2]. At the same time, more than 2 billion hectares of previously productive land are currently subject to degradation. By 2030, another 300 million hectares of land will need to be used for food production [2].

Various types of fertilizers are used everywhere to intensify soil productivity, but this may not always have a positive effect on the biosphere. Some fertilizers contain heavy metals, nitrogen fertilizers contain nitrates, which are converted into nitrites and then into carcinogens (if overused).
When mineral fertilizers are produced and applied to the soil, some of them are dusty, with worsening sanitary working conditions. "The evidence suggests that if the current vector of development of food and agricultural systems is maintained, we will face a permanent food instability and unsustainable economic growth in the future" [3]. It can also be said that climate change, "adversely affects crop yields, livestock and fisheries, especially in low- and middle-income countries, which increases pressure on natural resources and changes the geography and type of products produced" [3].

In connection with the above, studies were conducted on the possibility of intensifying plant growth by physical influences, which, unlike fertilizers (chemicals), do not affect the crop itself, but improve metabolic processes in plant cells by intensifying water exchange and improving photosynthesis.

2. Materials and methods

Study of the influence of visible spectra on the development of plants during the vegetative period. Mixed lighting was used to determine the effect of visible light spectra on the development of vegetative parts of plants. Light intensity of LEDs (Kingbright) was 150-200 mCd (table 1).

| Table 1. Characteristics of Light sources. |
|------------------------------------------|
| LED                                      |
| KA-3528QBS-G                             |
| KA-3528VGC-E                             |
| KA-3528 SYC                              |
| KA-3528 SEC                             |
| KA-3020SRT                                |
| Wavelength, (nm)                         |
| 465                                      |
| 530                                      |
| 580                                      |
| 610                                      |
| 660                                      |
| Color glow                               |
| blue                                     |
| green                                    |
| yellow                                   |
| orange                                   |
| red                                      |

Illumination at the beginning of the experiment was 2700-3000 luxmeter readings. Characteristics of the selected soil: in mg/L not less: nitrogen (NH4 + NO3) - 150; phosphorus (P2O5) - 270; potassium (K2O) - 300; pH of salt suspension - 6.0-6.5. The exposure period was 14 hours. A ROBITON NB70W was chosen as the voltage source. As the object of the study tomatoes of variety "Kolobok" of the selection and seed company POISK were chosen. They correspond to the requirements of international standards and GOST 32592-2013. The aim of the work was to study experimentally the reactions of tomato plants during the growing season, grown with light exposure spectra. A working hypothesis was put forward, according to which, by adjusting the light spectra falling on the plants at different stages of their growth, it is possible to influence the development of their vegetative part. During the first 12 days the objects of the study were monitored daily. In the following period the time between measurements was increased up to 1 week. The experiment lasted from 20.09.2019 to 06.12.2019.

Effect of alternating electric field on physicochemical properties of water in photosynthesis reaction.

In this work, a prototype device, which was manufactured in accordance with TU 4218-001-56316494-2004, was used as a source of variable frequency-modulated signal (VFMS). VFMS was a sinusoid (carrier frequency 50 Hz) with superimposed harmonics generated by microcircuits, working as a trigger. Signal characteristics: amplitude from 10÷180 V; frequency modulation range from 10÷12000 Hz. Distilled water according to GOST 6709-72 [4-9] was used for electrophysical experiments for determination of water properties. Seeds of rice X-26 (Oryza sativa), oats (Avena sativa) were chosen for research. The main studies were conducted in the period from January to December 2016-2017. Soil samples were taken according to TU 0391-001-11158098-2002. Soils were prepared for analysis according to TCVN 4047:1985.

3. Results

Study of the influence of visible spectra on the development of plants during the vegetative period.
Based on the studies, the light spectrum with a wavelength of 465 nm promotes the formation of leaves and plant growth, but does not affect the thickness of the stem. A direct correlation was found between the average plant height (in the control group, as well as illuminated by blue LEDs) and the sampling spread in these groups on the same day. The light spectrum, with a wavelength of 530 nm contributes to accelerated overall plant development during the first month. An increase in plant height compared to the control group was observed. During the experiment, a common feature of the plants in this group was revealed: their leaves were concentrated by the end of the experiment only in the uppermost part of the plants, rather than growing on the entire stem, as in the control group. The height from the ground to the leaves in the control group was 52.04% of the plant height, while in the section with green light this value was 92.56%. It was also found that the green spectrum had almost no effect on the number of leaves. These plants had the smallest stem thickness. Under the influence of the spectrum with a wavelength of 580 nm, a pulling of plants and their subsequent death within a month was observed. The spectrum, with a wavelength of 610 nm has a weak form of manifestation during the development of plants until flowering. The correlation table is dominated by weak and medium correlations. The orange spectrum had no visible effect on the growth and development of both stem and leaves and roots. When it replaced the more important spectra, plants grew weaker and less developed than in the control group. Probably, this spectrum can influence biological processes, such as oxygenic photosynthesis, which have weak visual manifestation. The absence of saturated green leaves is explained by the fact that plants in this group, having a weak root system, were unable to absorb a sufficient amount of dissolved organic matter from the soil. The group of plants illuminated by the spectrum with a wavelength of 660 nm grew significantly lower than the control. Nevertheless, the root system of these plants was even more developed. An increase in their mass was observed. Pearson correlation showed that in the red spectrum there was a very high direct relationship between the average height of plants and their stem thickness, a high direct relationship between stem thickness and the number of leaves. The relationship between height to the main leaves and number of leaves appeared to be a weak direct relationship. The red spectrum promotes the development of the root system and increases stem thickness. This can partially influence the development of the surface vegetative system.

Effect of alternating electric field on physicochemical properties of water in photosynthesis reaction.

Application of VFMS to irrigation water significantly changes the morphological characters of plants, and has a positive effect on germination energy, laboratory germination, sprout length and root system in rice and oat plants with increasing time of exposure to VFMS water, as the morphological characters of plants increase (figure 1).

Figure 1. Effect of irrigation water on growth processes and morphometric parameters of rice and oat seedlings in river substrate.
It was found that the duration of irrigation water treatment, regardless of substrate composition, affects the evaluated morphological parameters [10-15]. Experiments established a positive effect of irrigation treated water on the formation of leafy plant. As the time of exposure to VFMS water increases, so does the photosynthetic activity. As can be seen from figures 2 and 3, photosynthetic productivity of rice plants during the study was higher by 4.6±11.6% than the plants in the control. Oat plants in the experimental variants had photosynthesis productivity by 4.5±6.3% more than the control plants.

![Image 1: Net photosynthetic productivity of rice plants (mg/cm²/day).](image1)

![Image 2: Net photosynthetic productivity of oat plants (mg/cm²/day).](image2)

Since in modified water there is a change in size of structured formations associated with increased mobility of water molecules as a result of energy absorption of alternating electric potential, after electrophysical impact modified water, is characterized by faster molecules with higher speed and kinetic energy. According to the hypothesis, during the preliminary stage of seed germination, the direct sources of active molecules are, to different degrees, diffusion water and destructible shell of seeds, so it is possible to lead to an increase in cracks of their shell boundaries. The results of the study showed that the assumption of active molecules in the modified water, due to which an increase in germination energy and seed germination rate was observed. It can be said that the modified water increases the permeability of the seed shell, so seed germination increases.

It was found that polarized water affects the principle mechanisms in the root zone, in connection with which it is observed:

- Improvement of soil structure as a result of root system growth (physical effect);
- Increase of CO₂ content in the root system zone, which increases water solubility (chemical effect).
4. Discussion
In contrast to the chemical method of crop growth intensification, the polarization of plants by light spectra and the method of exposure to a variable frequency-modulated signal on irrigation water involves a physical impact on plants. Due to the absence of chemical compounds contained in fertilizers and stimulating plant development, there is no pollution of the environment, including fresh water. In addition, there is no accumulation of harmful elements in food, which has a positive impact on public health. By using these methods, it is possible to increase the efficiency of growing environmentally friendly crops.

The method of exposure to visible light spectra is aimed at accelerating the growth and development of both the whole plant and its individual parts. The study adds to the current information on the effects of visible light spectra. It allows us to judge about the existing relations between the development of individual plant parts, under their influence. The method of irrigation water polarization allows to increase fructification by about 14%, to improve soil structure in the root system zone, to increase germination and to increase morphological parameters of plants.

5. Conclusion
To implement the presented research, it is proposed to use a semi-automated technological scheme. When growing plants in greenhouse conditions it is proposed to use sensors to control soil and air humidity, air temperature, light level, water level in irrigation tanks. In the irrigation system it is proposed to introduce a source of variable frequency-modulated signal, a storage tank for irrigation, a pump, a block of valves and hoses. The application of VFMS to irrigation water significantly changes the morphological characteristics of plants, due to which accelerated germination, increased germination, development of sprouts and their bark system are achieved. The use of 660-nm and 465-nm LED lamps promotes accelerated stem growth, leaf formation, development of the root system of plants and their greater fruiting. To provide remote control, information from the sensors is transmitted through the expansion board, controller and Wi-Fi module to the user's mobile application, which allows you to choose manual or automatic mode of operation. Automatic mode provides operation based on the information received from the sensors and the required parameters set by the user. If there is a deviation from the set values, the system switches on the elements necessary to correct the deviation. Manual mode allows the user to remotely turn parts of the system on or off. In addition, the information transmitted to the mobile application allows the user to receive online information about the state of the system, atmospheric pressure and air temperature around it. One of the features of the used application is the possibility of its programming on the days of the week, which ensures the continuity of its work during a change of weather conditions or crops grown.

Thus, the proposed scheme allows intensification of plant growth by physical influences, namely by spectra of light and application of VFMS to irrigation water. In contrast to the used fertilizers, this scheme does not have a negative effect on the environment, it is environmentally safe. At the same time, like used chemical fertilizers, it improves the characteristics of grown plants. Application of this scheme can not only increase crop yields, but also improve sanitary working conditions. Remote control and automated operation realize the need to reduce the economic costs associated with the work of additional employees. In tandem with improved growth and fruiting, it can reduce the global price of organic products without compromising their quality, thereby partially solving the worldwide problem of hunger and lack of availability of these products in Asia and Africa.

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