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Use of innovative space technology in progressive crop production

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Abstract. Over the past decades, the mankind has been preparing for the exploration of the nearest planets. To this end, the problems of growing useful and nutritious biomass (providing food for astronauts and space colonists) are being solved. Technologies for securing the life of closed space systems are being developed. For the preceding decades, a lot of unique engineering solutions have been obtained that allow implementing the technology of progressive crop production in the conditions of the Earth. The ready-made solutions for growing vegetables and fruits, berries and mushrooms are offered. The introduction of these technologies for the foundation of agricultural greenhouses based on the methods of hydroponics and airponics has already been taking place. However, the majority of these decisions are devoted to the problems of plant care obtaining the maximum amount of biomass. It does not disclose the features of the application of these technologies in the conditions of Siberia and the Far North. This article reveals the consideration of engineering problems in developing agricultural greenhouse facilities in conditions equal to the conditions of the Far North.

1. Introduction

The analysis of articles, patents and literature on the development of agricultural greenhouses shows that at present the engineers of the Russian Academy of Sciences (in particular, the Krasnoyarsk Institute of Biophysics of the Russian Academy of Sciences) and Roscosmos, NASA specialists, scientists and engineers of the People's Republic of China are actively engaged in solving problems concerning with the provision future colonists of the nearest space objects food [1-4]. The unique results were obtained according to the standards for microclimate and lighting, creation of nutrient solution and the diagnosis of plant diseases to ensure the maximum amount of useful biomass.

However, the practical side of the matter faces a number of problems. It is necessary to solve the problem of cost optimization if we consider the problem of microclimate in developing agricultural greenhouse complexes for progressive crop production. Particularly these problems are important for areas equivalent to the North. And if we consider the program of the Arctic, then this problem becomes even more important. In these conditions, the problem of providing lighting for plants is generally critical; in the conditions of the polar night, plants cannot be provided with natural light. Thus, in the conditions of the polar night and low temperatures, the problem of development an agricultural greenhouse farm is an extremely energy-dependent problem. No less critical is the problem of producing nutrient solution on the ground. The fact is that ready-made nutrient solution consists of water and 5-1% of chemical elements in almost 95-99%. If we consider crop production in the central part of the planet, then an excellent transport system is established there. For the delivery of any cargo in areas equivalent to the territories of the Far North, and even more so the Arctic, each kilogram of weight is several times more expensive than in the central regions. It is also important to understand the seasonal characteristics of cargo delivery to the northern territories.

2. Conditions for the provision of microclimate

As it was mentioned above, natural light plays a weak role in development of agricultural greenhouse complexes in the conditions of the northern territories. So they must be neglected. This restriction requires agricultural greenhouse complexes manufacturing of a closed type. The implementation of this type of agricultural greenhouses means additional energy consumption for the organization of additional lighting. However, it can significantly reduce the cost of providing the necessary temperature regimes and humidity parameters. It should be also noted that each culture has its own unique conditions for growth and ripeness.

Consider the microclimate conditions on the example of strawberries.

It is necessary to maintain the air humidity in the range of 70-80% (according to some literature sources, a decrease in humidity to 60% is allowed) in the room for growing strawberries in hydroponics. The increased humidity can lead to the development of fungus, and at low rates plant growth is inhibited. So, it is necessary to maintain humidity within 80%, reducing the level by 5% during the flowering period, and by another 5% during the berries formation after planting the seedlings.

Strawberry is also particular about hydroponics to the air temperature in the room:

- During the planting the optimal temperature is upto + 20 ° C.
- Maintain the temperature from +20 to + 24 ° C, and at night it can be reduced to 16-18 degrees Celsius when the strawberry begins to flower.

Such conditions are the closest to natural and comfortable for strawberries.

It is also important to provide the plant with an optimal continuation of the periods of day and night [5, 6]. There are different classes of strawberries with a neutral day light (allowing for a low level of lighting). But even they need light, especially during the flowering period. The duration of flowering and fruiting depend on the intensity of lighting. The experiments show that at an 8-hour day, flowering occurs after 14 days, and the ovary appears 1.5 months after planting. By increasing the length of daylight hours to 16 hours, you can achieve flowering in 10 days, and the ovary in 35–37 days.

3. Development of the irrigation system

It is necessary to understand that the most promising are baseless technologies if we consider the organization of agricultural greenhouses in the northern territories, including the Arctic. Consider the most significant advantages of this technology before traditional methods of cultivation:

- Plants receive nutrients for growth and development. They are growing form powerful and strong stems quite quickly. The crop is higher than in growing on ordinary soil;
- The root system is constantly maintained by the necessary balance of humidity and air;
- The irrigation flow is controlled. It is impossible to pour it more than necessary. The hydroponic system, depending on the type and characteristics, will require refueling according to a certain schedule several times within a month;

- There are no problems in the dosage and choice of fertilizers; the grown crop always receives the necessary rate;
- The absence of soil leads to the fact that there are no diseases due to bacteria or soil fungus;
- Transplanting is much easier, it comes down to reloading the plant into a new container. Roots are not damaged. You only need to fill the substrate and pour the substance;
- Time consuming. The maintenance is reduced to performing only the simplest operations. With a minimum cost, the maximum yield is obtained.

Experts identify three schemes of hydroponic technology:

- Tidal. The peculiarity of this scheme is the following. A root part is periodically dripped into a nutrient solution for a short period of time. Then the liquid is removed. The roots "breathe."
- Capillary. The peculiarity of this scheme is the following. The root part is periodically dripped into a nutrient solution for a short period of time. Then the liquid is removed. The roots "breathe."
- Drip. It is quite a common technique. Here the solution in the root of the periodically served by drops. Passing through the filler, a part of the solution is used by the roots, the remaining solution is drained into the hopper, and then re-directed to drip irrigation.

4. Formation of nutrient solutions for plants

It should be noted that the nutrient solution for different cultures is different, so it is necessary to analyze the matter for a specific culture [7].

For example, for strawberries, the main nutrients are: nitrogen; potassium; phosphorus. Moreover, they need magnesium, calcium and sulfur, as well as hydrogen, carbon and oxygen, which they absorb from water and air. Unlike many other plants, strawberries prefer low salt levels. This can be checked with an electrical conductivity meter (EC) that measures the amount of salts in the nutrient solution. The ideal EC for strawberries is 1.2–1.5. Strawberries grow best within Ph from 5.5 to 6.8. It is measured using an inexpensive set of tester Ph. The increased or reduced Ph levels are adjusted by adding the Ph regulator to the nutrient solution.

A more detailed components structure of the nutrient solution for growing strawberries is presented in table 1 as follows, mg / l:

Table 1. The components of the nutrient substance.

Period	N	P	K	Ca	Mg	S
Vegetation	150	70	140	200	50	50-110
Fruiting	80	70	350	260	50	50-110
Buds formation	80	45	100	200	50	50-110

Microelementselements, mg / l: Fe-4; Cu-0,05; Mn-0,5; Zn-0,05; B-0,5; Mo - 0.05.

Therefore, it is necessary to make nutrient solutions independently when implementing progressive crop production in remote and hard-to-reach areas. It significantly saves on transportation.

5. Individual block complexes of progressive planting

In this direction, one can single out the Krasnoyarsk Scientific School on the development of the closed space systems. The Institute of Biophysics SB RAS, the Federal Research Center “Krasnoyarsk Science Center SB RAS” have been working for over 20 years at the International Center for Closed Ecological Systems for the development of the BIOS-3 project [8-10].

One of the latest power-plants of the center [11] that can be attributed to capsular personal type systems is presented in figure 1.

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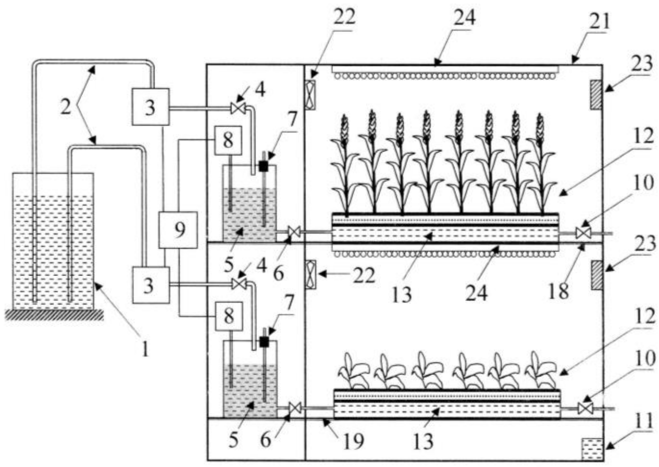

Figure 1. Hydroponic power-plant.

The power-plant for growing plants includes a supply system nutrient substance, blocks with plants 12, LED panels 24 and the housing 21. In the blocks with plants 12 tubular modules 13 are attached to the supporting surfaces 18 and 19 with the help of the holders 20. On the case 21 fans 22 are fixed, and on the opposite side of the housing 21 there are louvers 23 that provide an optimal air flow rate for the plants (figures 1, 2, 3).

The supply system of the nutrient solution to the tubular modules 13 includes a reservoir-source of nutrient solution 1; pipelines 2, pumps 3, solenoid valves 4, metering tanks 5 and solenoid valves 6. Dosing tanks 5 are equipped with adjustment tubes 7, by changing the immersion level of which the rate of nutrient solution supply to plants is regulated and liquid level sensors 8. Programmable controller 9 is electrically connected to pumps 3; electromagnetic valves 4 and 6, as well as liquid level sensors 8. Exhaust valves 10 are attached to tubular modules 13. Tubular modules 13 are composed of microporous tubes 14, on the outer cylindrical surface of which is fixed an elastic waterproof light film 16. The ends of the tubes 14 are closed with silicone stoppers 17.

The bedding grounds 15 in the form of hydrophilic ribbons for seed germination (figure 3) are placed in the upper part of the tubular modules 13. The bedding grounds 15 are made of moisture-absorbing polymeric material.

Two groups of red and white LED light sources with the possibility of independent control of the luminous flux from each group from 0% to 100%, depending on the needs of plants are fixed the LED panels 24. The intensity of lighting of plants is regulated by moving the height of the LED panels in the upper and lower blocks 12.

The power-plant operates as follows. Using the controller 9 they set the filling mode of the dosing tanks 5 with nutrient solution from the source tank 1 through the pipelines 2 using pumps 3. At the same time, the valves 4 are open and the valves 6 are closed. When a certain level is reached, the level sensor 8 is triggered, the signal from which with the help of controller 9 initiates closing of valve 4, opening valve 6 and turning off pumps 3. The nutrient solution flows by gravity from dosing tanks 5 into microporous tubes 14 by gravity. After filling the micro porous tubes 14 with a nutrient solution, the remaining air is removed from them, alternately opening and closing the valves 10. When the microporous tubes 14 are being deactivated, some nutrient solution flows out and is drained into the mortar receiver 11. The adjustment tubes 7 are set at such a level that after filling in the micro porous tubes 14, the surface of the bedding ground 15 is wetted. After that, plant seeds are placed on the bedding ground 15, turn on the LED panel 24, fans 22 and coolant circulation inside the LED panel 24. The roots grow into the space between the micro porous tube 14 and the film 16. While the roots grow, a gap between the micro porous tube 14 and the film 16 increases due to the stretching of the film 16.

Figure 2. Module with wheat plants.

Figure 3. Module with lettuce plants.

The level of the nutrient solution in the dosing tanks 5 as it is absorbed by the plants is reduced to a minimum level, and by the feedback signal from the liquid level sensor 8, the controller 9 closes the valve 6 and opens the valve 4. In the upper and lower blocks 12 several tubular modules 13 can be placed (from 2 to 10 modules are given in figure 2), each of them is connected to a separate pipeline to the dosing tanks 5 through the solenoid valve 6. The connection of the tubular modules 13, sowing of seeds and fruiting are carried out sequentially with a time lag, depending on the length of the growing season of a particular plant species and a number of conveyor steps.

Some experiments were conducted on the cultivation of wheat and lettuce in this power-plant. The results can be seen in figures 2 and 3. They confirm the success of the experiments. It should be noted that these plants are not only suitable for growing wheat and lettuce, but they are able to create the required conditions for growing any plant. It makes them extremely important for the cultivation of healthy and tasty products in the conditions of the Far North.

6. Conclusion

The article considers the necessary conditions for growing strawberries and provides detailed data on the technology of growing strawberries that will help to organize agricultural greenhouses for the production of this crop, including the territories of the Far North. The example of developing an individual box for growing plants whose growth does not exceed 40 cm (berry, fresh greens, vegetables, etc.) is given. We gave the results of growing lettuce and wheat in the analysis of the power-plant.

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