Automation and digitalization of healthy fruit and berry plants reproduction

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Abstract. High-quality planting material is a condition for increasing productivity and labor productivity in the cultivation of agricultural products. High-quality planting material is material that is free from harmful pathogens. The process of plant healing requires significant time and material costs. However, with the proper organization, plant healing can be significantly accelerated and cheapened. The main condition for accelerating this process is maximum automation and digitalization of all stages of clonal micropropagation. The article shows the results of many years of work on the cultivation of healthy planting material. Variants of possible improvement of planting stock recovery are proposed with the introduction of the necessary hardware and software at specific stages of recovery and reproduction.

1. Introduction
According to Rosstat, the volume of investments in the digitalization of agriculture and the introduction of information technologies amounted to about 0.2% of the total investment in this area (or 0.85 billion rubles). This indicator is the industry's lowest indicator, showing a low level of digitalization of domestic agriculture. However, this indicator shows that the industry has the most significant potential for investment in ICT technologies. One of the most important areas of application of digital technologies is the organization of the reproduction process of healthy planting material of fruit and berry plants.

Scientists of the Michurin State Agrarian University carried out many years of consistent work in apple cultivation. To date, this work has led to the creation of more than 20 low-growing clonal apple rootstocks of various growth rates and adaptable to many different regions, both in Russia and in many foreign countries. This process makes it possible to grow apple orchards of varying degrees of intensification [1].

In addition, much work has been done to improve the health and clonal reproduction of clonal rootstocks of apple trees and promising varieties of strawberries [2]. Based on the work's results, mother plants of clonal rootstocks of apple and strawberry were laid and successfully cultivated. However, according to the accepted rules, and as experience shows, it is necessary to regularly monitor the state of plantings and the presence of primary mother plants of crops grown [3-4].

Due to the possibility of contamination of cultivated plants in the open field with sucking and leaf-eating pests, the optimal way out is to rotate uterine production plantings laid by the healed material regularly. As noted above, this currently requires relatively high costs, including manual labor and attention [5, 6].

Moreover, automation and digitalization at the stages of healing and clonal micropropagation of grown crops can make a significant relief.
In this regard, the research aims to analyze the directions and assess the scale of application of automation and digital technologies in the recovery and reproduction of clonal rootstocks of apple, strawberry, and other crops.

2. Materials and methods
The study was carried out based on the long-term experience of the Problem Laboratory for the selection of low-growing clonal rootstocks of apple trees and other crops, the agrobiostation of the Social Pedagogical Institute of Michurin State Agrarian University, the laboratory of biotechnology of the CIT in Michurinsk-Science City, as well as the analysis and processing of information from websites of electronic libraries and companies, engaged in research in the field of crop cultivation.

The research is carried out in connection with the Russian Federation's adoption of July 28, 2017, No. 1632-r of the program "Digital Economy of the Russian Federation."

3. Results and Discussion
The task is to successfully carry out the healing and clonal micropropagation of clonal rootstocks of apple trees and other crops and improve these technologies. For this task, it is necessary to introduce automation and digital technologies at the stages of thermotherapy, introduction into culture, proliferation, rhizogenesis, and adaptation.

The decisive factor at the stage of thermotherapy is the preservation during the entire period of the modes of humidification, illumination, and temperature in a heat chamber, optimal for plant growth.

We created a two-sectional heat chamber with an insulated soil layer and placed it at room temperature. This invention makes it possible to stably control the temperature of the soil without additional constant cooling with water, which significantly reduces its costs and the costs of its circulation.

The installation of humidity control sensors (sensors) and the connection of the spray system to them allow automating the irrigation process. This device eliminates the need for constant monitoring and manual watering, which is very important while maintaining the regime's stability in small volumes of the soil layer in the root zone of plants.

The following condition for successful thermotherapy of plants is preserving the illumination mode for specific plants (crops, varieties) in the required parameters inside the heating chamber. As a rule, for clonal apple rootstocks, this mode is 16 + 8 hours, and for strawberries – depending on the specific variety. In this case, the light spectrum, which should be close to the sun, is of great importance. In addition, the degree of illumination is of great importance, which is in the range of 3-6 thousand lux and more (depending on the culture).

Suppose the thermal camera is placed near the room window with the installation of a light sensor. In that case, it is possible to stabilize the degree of illumination, which can significantly save electricity on sunny days, which is important for long-term thermotherapy. An indicator of the optimal illumination for clonal apple rootstocks is anthocyanin color in the leaves, which is characteristic of this rootstock. In strawberries, the degree of saturation in the leaves of chlorophyll.

The temperature regime inside the chamber is provided by incandescent lamps connected to a thermostat and located above the plants. Recommended at the stage of thermotherapy are temperatures close to 38°C (38 ± 1°C) [7].

An important condition for digitalizing the healing process at the stage of thermotherapy is the control over life factors by sensors installed by video cameras and appropriate software according to certain algorithms controlled by a phytomonitor. Work on creating such a complex is currently being carried out by employees of the Michurinsk State Agrarian University [8].

The creation of this complex will make it possible to create a controlled system with a significant reduction in the influence of the human factor and save on electricity and water consumption. All the necessary conditions will be provided not by a person based on his organoleptic assessment of the ongoing processes but by an automated system. The automated system operates based on data obtained...
by sensors and characterized, with a high degree of reliability, plants' state, and the need to change the factors affecting plants to the required degree.

The preservation of a complex of favorable conditions contributes to the rapid growth of plants and the inactivation of viral pathogens. After a certain period, this process allows significantly reducing the pressure of the viral infection, especially in the apical part of the plant, which is the task of the thermotherapy stage.

According to T.D. Rope [8] and other researchers, the timing of thermotherapy, depending on the culture and state of plants, may be different. The search for these terms is relevant since the process of thermotherapy itself is very costly. Our experience shows that the successful completion of the thermotherapy process in apple clonal rootstocks is a period of 40 to 70 days. Previously, in the absence of PCR analysis, it was not possible to carry out an express analysis to present the desired viral infection. It is realistic to evaluate the effect of thermotherapy already from the 40th day by selecting the apical parts of the tested plants. This circumstance also makes it possible to improve the technique and save money and time significantly. The next stages for the successful use of digital technologies are the stages of actual reproduction (proliferation) and rooting (rhizogenesis).

At these stages, in addition to the competent selection of nutrient media, temperature, plant illumination, and the spectral composition of light are of great importance. So, the optimal temperature at these stages is the temperature in the culture room in the range of 23-25°C. Illumination is about 6 thousand lux, the duration of the light period is 16 + 8 hours for crops of a long day. For strawberries, the duration of the light period depends on the biological characteristics of the variety. The light spectrum (blue, green, yellow, red, and other lights) is of great interest at these stages. Since by using the flux of light of different wavelengths, various goals can be achieved – the amount of growth, the growth of biomass, and other goals.

The monitor can control the processes of reproduction and root of plants by installing the necessary sensors for temperature, illumination, light spectra signaling the state of the environment on the shelves and fixing the state of plants – explants, video cameras according to certain algorithms.

The possibility of creating a single difference factor under these conditions (when isolating specific racks) will allow obtaining reliable facts about the influence of a particular factor of plant life on plants.

Plants grown in vitro have many features: the leaves of these plants do not have protection (cuticles), the stomata are often constantly open, the roots have only a primary structure, and, being planted in vivo without special preparation, they experience severe stress, leading to death.

During adaptation in plants, a restructuring of a complex process occurs within the boundaries of the genetic norm of reaction. At the same time, the restructuring itself should take place gradually with a slow tightening of environmental conditions.

If, when transplanting explant plants into a greenhouse, the conditions should immediately be close to in vitro conditions (temperature about 25°C, humidity 95-100%, substrate close to sterile), then by the end of the plants' adaptation period should be resistant to open ground conditions. For this, it is necessary to change the growing conditions of explants in the greenhouse gradually. These changes should be smooth, excluding sudden changes in temperature and humidity. Achievement of such indicators will allow the use of automated systems that make it possible to make changes in the factors affecting explant plants in the greenhouse. The operation of such systems should be based on diagnostics of the state of plants, as well as changes in environmental factors, which, in addition to everything, may depend on temporary conditions, for example, the time of day. Therefore, such a system should include sensors that assess humidity, the temperature in the greenhouse, growth rates and functional state of plants, signal paths, and a head unit. The head unit performs the functions of processing incoming information, analyzing it, and, based on this analysis, generating the necessary decisions to maintain the necessary conditions or changes through the executive devices' operation. Such a system allows smoothly changing the growing conditions of explant plants in the direction of their tightening and gradual departure from greenhouse conditions to approaching open ground conditions.

Accurate work based on the assessment of the current state of explant plants, the factors affecting them in the greenhouse, and their smooth changes allows making the process of obtaining a healthy
planting material for fruit and berry plants standardized and independent of various factors, such as weather or the human factor.

Thus, for successful adaptation, it is necessary to have a greenhouse with sufficient equipment: curtains, ventilation, adequate irrigation, sensors for temperature, humidity, illumination, which will transmit information to the monitor, which, based on the developed algorithms, evaluates the readings and makes decisions on the operation of executive devices [8].

As many years of experience show, most often, the results of adaptation depend on the human factor: timely competent decision-making to maintain the necessary conditions for adaptation, and the introduction of new technologies will significantly reduce the cost of manual labor and maintain a favorable regime for increasing the yield and quality of adapted plants.

Thus, the introduction of automation into obtaining a healthy planting material is an important condition for ensuring the production of high-quality plants. The use of automation allows eliminating the possible negative impact of the human factor. Provide plants with stable optimal constant conditions necessary for their normal development, independent of external factors. In this regard, the creation of such systems is a promising and necessary direction of scientific activity. The implementation of the results into practice and production will make the process of reproduction and obtaining a healthy planting material more efficient both from an economic point of view and from the point of view of the quality of the obtained planting material.

4. Conclusion
The modern development of automation and the introduction of digital technologies can significantly increase the efficiency of healing agricultural plants from pathogenic viral diseases at the stages of thermotherapy, proliferation, rhizogeny, and the adaptation of explant plants to in vivo conditions.

The possibility of carrying out PCR analysis makes it possible to determine the timing of thermotherapy for specific plants, which significantly reduces the time and material costs at this stage.

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