The economic aspect of new ways of obtaining innovative forest biotechnology products

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Abstract. The article discusses new methods for producing woody forest plants used in traditional in vitro micro-cloning technology. Each method is considered from the point of view of economic and biological effectiveness. Organizational models for each method have been developed and constructed with the help of a specialized software product. The stages of obtaining woody forest plants have been described. Standard and technological sheets have been constructed and economic indicators of growing forest trees have been determined under optimal production conditions for each method of in vitro micro-cloning technology. The production costs for the in vitro cultivation of woody forest seedlings are determined using the considered methods. And their economic and ecological-biological efficiency is proved. It has been established that the high cost of the applied methods of biotechnology in obtaining woody forest plants does not allow competing with plants obtained by traditional microcloning technologies in vitro. A way out of the situation is possible only due to the transition from laboratory to production conditions. It reduces the complexity of work through the use of specialized equipment and automation of microclone growing processes.

1. Introduction

Forest complex of Russia is increasingly facing the problem of a shortage of high-quality and affordable wood raw materials, what is the main cause of the economic instability of the processing enterprises. However, the state of affairs in the field of reforestation and the cultivation of forest species is assessed as unsatisfactory in Russia as a whole in recent years. The area of 31749,9 ha needs for reforestation, while only 850 thousand hectares are restored annually. The proportion of forest crops created using planting material with improved hereditary and predetermined properties is 4.3 %.

The effectiveness of reforestation processes in the region's forest fund is determined by the quality of forest planting material [1]. In the current situation, one of the effective measures is the use of various technologies, which make it possible to obtain forest trees with accelerated target properties at an accelerated time.

A large number of genetically modified trees (GMT) with modified or new characteristics have been produced in the EU over the past 15 years. It gives sufficient economic and environmental benefits, such as lower production costs and less pressure on local forests.
Recently, the potential of using nanoparticles in microclonal propagation of plants has been demonstrated in the field of biotechnology.

There is information about the positive effect of metal nanoparticles, which are antimicrobial agents of a broad spectrum of activity, in some cases possessing antiviral properties on the resistance of trees.

In recent years, the use of nanoparticles successfully led to the removal of harmful microorganisms from explants and demonstrated the positive role of nanoparticles in the micro propagation of forest trees [2]. Nanoparticles have influenced plant cell cultures and, therefore, can significantly affect various aspects of plant biotechnology, including methods of disinfecting cell cultures, callus differentiation, genetic transformations, somaclonal variations and the production of secondary metabolites. An example is the results of experiments with silver nanoparticles used to disinfect explants [3,4].

The recent studies show that positive experience has been accumulated in creating resistant to diseases and pests of tree species obtained by various methods of biotechnology in a number of countries.

To achieve all of these goals, it is necessary to critically consider alternatives and new technologies for the production of forest trees, given the importance of accelerating their selection efforts [5]. This is only possible when used in practice for the creation and production of innovative products of forest biotechnology organizational models.

The researchers note that the management of the production and economic system, which introduces innovations under the influence of various factors, is based on the presentation of the innovation life cycle, which requires the construction of an organizational model that will describe these processes and obtain scientifically based effective development paths for the production system and economy by drawing up effective project portfolios [6,7].

Organizational modeling of industrial and economic relations in innovative industrial complexes allows not only to carry out the planning function, but also to control all the described actions of the elements of the established technological chain [8]. Moreover, the presentation of technological processes of production of innovative products in the form of organizational models will help to solve the main problems faced by innovation leaders, namely: the problem of choosing and organizing information management tools, the problem of finding optimal values for project parameters and the problem of studying the project and playing out possible situations on models [9].

The organizational models presented by us for the creation and production of innovative forest biotechnology products will allow us to manage the process of developing innovative products at each technological stage of cultivation.

2. Methodology
The estimated consumption for the planning and execution of specific work on the production of planting material (microplants) in vitro according to the adopted technological schemes was made in the form of cash-flow chart. The methods of working time photographs, time observers, and rationing were used in the construction and development of regulatory and technological sheets. The production cost of growing microclones using different technologies was determined on the basis of the direct costs of the remuneration of employees directly involved in production, equipment maintenance (depreciation), purchase of materials and fuel, and consumed electricity.

Evaluation of the economic efficiency of micro-cloning technologies used in vitro was carried out using the following indicators as net present value (NPV) and profitability index (PI). These are relative indicators that characterize how the income from capital investments covers the costs of them. It is calculated by the formula:

$$NPV = -IC + \sum_{t=1}^{n} \frac{CF_t}{(1+i)^t}$$  \hspace{1cm} (1)
where IC – initial investment; CF$_t$ – cash flow discounted over time; and i – discount rate (percent).

$$PI = \frac{\sum CF_t}{IC} \left(1 + \frac{i}{100}\right)^t$$  \hspace{1cm} (2)

The decision on this criterion was made as follows:
- If PI>1, then the project is accepted, since the revenues from the investment project exceed the costs of it;
- If PI<1, then the project is rejected, since the income on the investment project is less than the estimated costs.

Business Studio 4.0 software product was used when developing an organizational model of business processes of growing forest seedlings.

Two technologies of *in vitro* microcloning of woody forest plants are considered:
- Using nanotechnology approaches;
- Using approaches of genetic engineering and transformation.

3. Results

We have built working versions of process and subprocesses maps that include descriptions of techniques and operations at each stage of the applied micro-cloning technology of woody forest plants (consumed and attracted material, labor and financial resources).

Figure 1 presents a general contextual diagram of activities for the development and creation of regenerants of forest woody plants in vitro using nanotechnological approaches and a context diagram of activities for the development and creation of genetically modified forest trees in vitro.

For an objective analysis and determination of the cost of creating genetically modified forest tree plants *in vitro*, the decomposition of the context diagram into a sequence of processes of the presented technologies includes the same set of cumulative techniques:
- production planning;
- preparation of components and resources;
- obtaining primary *in vitro* explants of forest woody plants;
- rooting of isolated shoots and their multiplication (clonal micropropagation) *in vitro*;
- adaptation of microplants in conditions of non-sterile soil in the laboratory and re-growing in conditions of closed soil (greenhouse) (figure 1).

The use of organizational models for the substantiation of technology is justified [10, 11].

The *in vitro* micro-cloning technology of woody forest plants using genetic engineering and transformation approaches and nanotechnological approaches can be used as a methodological support for growing seedlings of woody plants in forest seed breeding centers of the Russian Federation and greenhouse complexes.

Using the process approach, standard and technological chart have been constructed and economic indicators of seedling growing under conditions of optimal production have been determined (table 1).

The calculations are performed on the example of poplar regenerants. Monitoring of technological processes was carried out, the duration and costs were determined at each stage of the considered technology of microcloning *in vitro* of woody forest plants for the standard and technological charts.
Figure 1. Stages of *in vitro* micro-cloning technology of woody forest plants using different approaches.
It has been established that a significant increase in the cost of the *in vitro* production of woody forest plants using microcloning technology using genetic engineering and transformation approaches is associated with the use of high-tech equipment necessary for organizing the operation of regeneration and selection of transformants, which requires high maintenance and maintenance costs. The most time-consuming and cost-intensive stage of the technological process when using in vitro micro-cloning technology of woody forest plants using nanotechnological approaches is the process of regenerating in greenhouse conditions. While applying the approaches of genetic engineering and transformation, the process of obtaining primary explants of in-vitro forest woody plants is most expensive. This is due to the fact that at this stage of the technological process genetic transformation of the explants of forest aspen plants with the use of an agrobacterial suspension is carried out, which requires the use of expensive materials and highly skilled labor. Thus, the production cost of one regenerant obtained by micro-cloning technology using genetic engineering and transformation approaches is 1,200 $, for regenerants obtained by micro-cloning technology using nanotechnological approaches – 700 $. When growing forest seedlings in greenhouse conditions, a significant part of the costs is not included in the production cost. According to various estimates it amounts to 25% of the costs. With this in mind, the total cost of growing microclones using genetic engineering and transformation approaches will be 1,400 $, using nanotechnology approaches - 900 $.

| Table 1. The cost of growing woody forest seedlings *in vitro*. |

| Indicator                                      | Value               | In vitro microcloning technology of woody forest plants using genetic engineering and transformation approaches |
|------------------------------------------------|---------------------|-----------------------------------------------------------------------------------------------------------------|
| General manufacturing costs, $                | 1,103,700           | 1,361,200                                                          |
| The cost of labor production workers, $        | 793,500             | 1,196,000                                                          |
| Raw materials and basic materials, $           | 1,111,100           | 1,377,800                                                          |
| Fuel and energy for technological purposes, $  | 95,200              | 278,400                                                            |
| Total production cost, $                       | 3,103,500           | 4,213,400                                                          |
| Overhead costs                                 | 775,900             | 1,053,400                                                          |
| (25% of production cost), $                    | 3,879,400           | 5,266,800                                                          |
| Total cost, $                                   | 69,000              | 69,000                                                             |
| Microcooler output                             | 700                 | 1,200                                                              |
| Regenerant production cost, $                  | 200                 | 200                                                                |
| Regenerant Overhead, $                         | 900                 | 1,400                                                              |
| Profit 25%, $                                  | 200                 | 300                                                                |
| Regenerant price without value added tax, $    | 1,040               | 1,700                                                              |

When determining the price of one seedling, we assumed a profit rate of 25%, taking into account what the sale price of microclones obtained by the microcloning technology using genetic engineering approaches is 1,700 $ and for the regenerants obtained by the microcloning technology using nanotechnological approaches – 1,040 $ (table 1).

The net present value (NPV) of regenerants obtained by in vitro microcloning of woody forest plants using genetic engineering and transformation approaches is 352,000 $; using nanotechnological approaches – 3,100 $, which indicates that total cash receipts are higher than total costs (figure 2-3).
The applied technologies for producing regenerants of woody forest plants in vitro can be considered effective ones, since NPV > 0.

![Figure 2](image2.png)

**Figure 2.** Net present value of regenerants obtained by in vitro micro-cloning technology of woody forest plants using genetic engineering and transformation approaches.

![Figure 3](image3.png)

**Figure 3.** Net present value of regenerants obtained by in vitro micro-cloning technology of woody forest plants using nanotechnological approaches.

4. Conclusion

The transition to new technology in the sectors of the economy, including forestry, involves its economic justification. The presented organizational model of stages of the technology of microcloning of woody forest plants using different approaches in vitro can be used as methodological support for the cultivation of innovative forest products in breeding and seed centers.

The scope of work was determined, and normative and technological maps were developed for each phase of the applied technology for growing cloned wood forest plants in the laboratory.

In the course of research, it was found that the applied technologies of microclonal propagation of woody forest plants in vitro are expensive mostly due to the high labor intensity of the work performed, highly qualified of the work performed, and expensive materials and equipment.

Based on the calculation results, it was concluded that planting material grown and adapted in the greenhouse using the selected technologies will not be competitive. First of all, the price is not competitive with peers (forest seedlings grown using traditional technologies). However, the biological characteristics of microclones grown in vitro are superior to the biological characteristics of similar tree species grown in open ground. We can conclude that the introduction of the technologies in practice will be economically feasible only if the transition from laboratory to production
conditions. This will reduce the complexity of the work through the use of specialized equipment and automate the process of growing microclones.

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