Improvement of potato cultivation technology

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Abstract. Existing methods for assessing the economic efficiency of the system of machines and technological methods contain numerous similar indicators. The multifaceted nature of the problem, its dynamism also cannot be covered by a single criterion – the value of the reduced costs. A method of systematic research and analysis of the technological efficiency of the production process has been developed to improve the technological processes and technical means for potato cultivation and to achieve higher economic indicators of agricultural production development. A generalized criterion characterizing the efficiency of the working process as a whole, which can be used to evaluate various technological operations in the production of potatoes, is obtained. Various technological processes performed by the working bodies of combined and serial machines were analyzed to verify and confirm the effectiveness of the developed provisions. At the same time, vector quantity was adopted as the main criterion for the comparative evaluation of machines and technologies. As a result of the implementation of this method, a scientifically based technological map for the cultivation of environmentally safe potatoes is proposed. The complex of agricultural practices for the implementation of the proposed technology is selected taking into account soil and climatic conditions and is designed for the cultivation of potatoes with minimal labor and money. The use of technological operations, such as the distribution of straw rolls on the field with its incorporation into the soil, germination of seed potatoes tubers in the peat-mineral shell, inter-row processing with sprinkling of plants with soil, simultaneous removal of the tops by crushing in the process of harvesting combines can significantly reduce costs in the production of potatoes.

1. Introduction

The peculiarity of agriculture, as an industry, is largely due to the need to preserve and improve soil fertility. As well as technological operations on a wide area, broken in time by the biological cycle of plant development. Traditional technologies, involving the execution of operations with a time gap, are inferior to new technological schemes of combining operations performed in one pass of the machine unit. This allows reducing the number of machine passes through the field, reduce labor and material costs by creating a more favorable regime for the development of plants and technological operations in the optimal time, to obtain higher yields of cultivated crops [1,2].

Reducing the cost of potato production is one of the main tasks of potato growers in Russia. In the cultivation of this crop, the cost largely depends on the technology of potato production [3,4].

The degree of perfection of the specific technology of potato cultivation is determined by the fact that the quality indicators of the machines used in the production process meet numerous
agrotechnical requirements. In addition, technical and economic indicators are taken into account: productivity, labor and cost per unit of output [5,6].

Agricultural machines and tools operate in conditions determined by the interaction of processes of different nature, and therefore their design requires a comprehensive solution of technical, biological, social and technological problems [7,8].

The industrial technology of potato cultivation is based on the maximum mechanization of the processes of its planting, cultivation and harvesting, but has a number of disadvantages, which include the inability to extend the growing season and obtain physiologically full tubers with dense skins in the early period, the unsatisfactory operation of existing potato planters in the planting mode of sprouted tubers and the discrepancy between the known methods of germination and the requirements for the preparation of seed potatoes [9,10].

Comparative assessment of the level of technical means, analysis of options for mechanized technological processes and identification of the most effective among them is a complex task, which is associated with a variety of performance indicators. Existing methods for assessing the economic efficiency of the system of machines and technological methods contain numerous similar indicators. The multifaceted nature of the problem, its dynamism also cannot be covered by a single criterion – the value of the reduced costs.

2. Materials and methods

Theoretical studies were conducted on the basis of generally accepted laws of classical mechanics, mathematics and mathematical statistics. Experimental studies were conducted in accordance with the generally accepted methods of experiments, the current standards and regulations. Calculation and processing of the obtained results were performed by methods of mathematical statistics using a PC with Microsoft Excel 2010 and Statistica application programs.

A generalized labor productivity is taken in the form of an integral quality indicator, reflecting the ratio of the total positive effect of consumption to the total cost of total labor for the creation and use of products:

$$
\varepsilon_c = \frac{\sum \Xi}{(S_a + S_n)} = \frac{k_2 \sum C_i}{(C_{np} + H_i)}
$$

where $\sum \Xi$ - total useful effect; $S_a$ - the cost of creating hardware; $S_n$ - the cost of their operation (consumption); $k_2$ is a generalized indicator of the quality of work performed (products); $\sum C_i$ is the total cost of functioning of a machine or unit for the production of a unit of production (unit cost of a product of a given quality); $C_{np}$ - reduced costs in units of current expenses; $H_i$ - the cost of unit expenses of living labor, referred to the unit of production or output.

According to the $\pi$-theorem of the similarity theory, the functional dependence between the quantities characterizing the process can be represented as a relationship between the similarity criteria made from them. Therefore, from the obtained set of similarity criteria, taking into account their logical relationship, it is possible to obtain one generalized criterion characterizing the efficiency of the workflow as a whole:

$$
J = \frac{(Q_T G_T P_T k_c \tau_c)}{10^4 N_y M_y q_T W}
$$

where $W$ - hourly capacity of the unit, ha / h; $G_T$ is the intensity of technological cargo flows, kg / m²; $M_y$ is the specific material consumption of the technological process, kg / ha; $q_T$ - specific fuel consumption, kg / ha; $k_c$ is an indicator of the speed of the technological process; $\tau_c$ is a measure of the intensity of total costs, characterized by the ratio of current costs to reduced ones; $P_T$ - technological material consumption of the production process, kg / ha; $Q_T$ is an indicator characterizing energy consumption for processing and distribution of technological material, N · m / s; $N_y$ - total power consumption, kW.
The values of the complex indicators (1) and (2) can be represented either as a vector space or as a functional that takes into account their weight in order to comprehensively evaluate the effectiveness of the entire production process and obtain its quantitative characteristics. Thus, various technological processes carried out by the working bodies of combined and serial machines were analyzed to verify and confirm the effectiveness of the use of the developed provisions. At the same time, the vector value was adopted as the main criterion for the comparative evaluation of machines and technologies.

$$F^2 = \varepsilon^2_x + J^2$$  \hspace{1cm} (3)

A comprehensive indicator obtained to assess the effectiveness of new technology reflects the specifics and content of the process of increasing the productivity of social work. It characterizes the efficiency of the mobile unit, reflects its technical level and the rationality of the technological impact on the processed environment, as well as the intensity of the workflow.

3. Results and discussion

As a result of the calculations of the parameters of the system analysis, a graph of the dynamics of the complex indicator of the efficiency of tillage equipment, depending on the speed of translational motion and its width, which is shown in Figure 1, was built.

![Figure 1](image.png)

**Figure 1.** Dynamics of changes in the complex index of efficiency of tillage equipment depending on the speed of translational motion: F - a comprehensive indicator of the efficiency of tillage equipment; V - forward speed, m / s; B - width, m.

As follows from the graph, a rather intensive increase in the value of the complex index occurs with an increase in the speed of movement of the aggregate. Moreover, the intensity of its growth increases more sharply with the increase in the width of the working grip. If the plows with a width of 1.40 ... 1.75 m intensive growth of this indicator begins at a speed of 2.60...3.0 m / s, with a width of 2.8 m corresponding to its values are achieved at a speed of 1.40...1.5 m/s. Therefore, wide - angle plows with the number of buildings from 8 to 10 are most efficiently used at speeds of about 2 m/ s, while the four-and five-body plows similar indicators are achieved only at speeds of 3.7...4.0 m/s.

But the width of the capture cannot be increased indefinitely, since this growth is limited both by the power of the energy means that aggregates the combined machine, and by the impossibility of uniform execution of the technological process on the entire width of the work corresponding to
agrotechnical requirements. This also applies to the number of types of weapons that can be aggregated at the same time.

Therefore, on the basis of many years of experience of advanced potato farms in our country, using some agrotechnical requirements of foreign technologies, based on the analysis of technological schemes of construction of the production process, assessment of its organizational and technical level, a comprehensive assessment of the effectiveness of technology and the intensity of mechanized technologies was developed scientifically based zonal technology of production of commercial potatoes with minimal labor and funds, the list of operations which is presented in the technological map (Table 1).

**Table 1. Technological card on the cultivation of potatoes**

| Ser No. | List of operations                                                                 | Agrotechnical indicators                      |
|---------|-----------------------------------------------------------------------------------|-----------------------------------------------|
| 1       | The distribution of rolls of straw on the field with simultaneous incorporation into the soil | Processing depth 8 ... 12 cm.                  |
| 2       | Loading of fertilizers                                                             | -                                             |
| 3       | Fertilization                                                                     | 50-60 t / ha                                  |
| 4       | Autumn plowing with a turnover of formation                                        | Processing depth 8 ... 12 cm.                  |
| 5       | Sorting seed potatoes into fractions                                               | Weight of tubers 50 ... 80g.                  |
| 6       | Loading of seed potatoes                                                           | -                                             |
| 7       | Transportation of seed potatoes                                                    | -                                             |
| 8       | Germination of seed potatoes in the peat-mineral shell                             | The duration of 25...30 days                   |
| 9       | Surface treatment of soil                                                          | Processing depth 8 ... 12 cm.                  |
| 10      | Main processing of the soil                                                        | Processing depth 8 ... 12 cm.                  |
| 11      | Loading of seed potatoes                                                           | -                                             |
| 12      | Transportation of seed potatoes                                                    | -                                             |
| 13      | Transportation of chemicals for processing tubers                                 | -                                             |
| 14      | The cutting ridges with the application of mineral fertilizers                    | Processing depth 8 ... 12 cm.                  |
| 15      | Planting potatoes with sprinkling                                                  | Sprinkle with soil 1.5 ... 2 cm thick          |
| 16      | Leveling the field surface, shelter tubers                                       | Method of movement - diagonal                  |
| 17      | Pre-emergence treatment of fields                                                  | -                                             |
| 18      | Treatment of the seedlings                                                         | -                                             |
| 19      | The first inter-row treatment with sprinkling of plants with soil                  | The depth is 5-6 cm, the protective zone of 5 cm. |
| 20      | The second inter-row treatment with sprinkling of cultivated plants with soil      | The depth is 5-6 cm, the protective zone of 5 cm. |
| 21      | Treatment of potato against fitofitozora                                          | Preparation                                   |
| 22      | Potato hilling                                                                    | -                                             |
| 23      | Combine harvesting of potatoes with simultaneous crushing of a tops and destruction of an imago of the Colorado potato beetle | -                                             |
| 24      | Transportation of potatoes                                                         | -                                             |

The use of technological operations, such as the distribution of straw rolls across the field with its incorporation into the soil, sprouting seed potato tubers in a peat-mineral shell, inter-row processing with plant sprinkling with soil, the simultaneous removal of the tops by crushing during harvesting with potato harvesters can significantly reduce the costs of potato production.

The developed technology of potato production provides for:
- rational use of organic fertilizers and balanced use of mineral fertilizers;
- creation of planned on-farm seed production on a virus-free basis;
- provides conditions for sustainable harvesting;
- organization of specialized contract and rental units for potato cultivation in farms, which allow obtaining high yields and high quality products;
- timely and correct performance of works on protection of plants from weeds, pests and diseases, using modern equipment, without polluting the environment.

4. Conclusions
The complex of technological operations for the implementation of the proposed technology is selected taking into account soil and climatic conditions and is designed for the cultivation of potatoes with minimal labor and money.

The introduction of the proposed zonal technology of cultivation and har-vesting of potatoes can improve productivity and reduce labor costs by 30...35%.

A comprehensive indicator obtained to assess the effectiveness of new technology reflects the specifics and content of the process of increasing the productivity of social work. It characterizes the efficiency of the mobile unit, reflects its technical level and the rationality of the technological impact on the processed environment, as well as the intensity of the workflow.

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