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Technical-economical analysis of design solutions of technological complex of industrial production of entomophages

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The purpose. To determine link of economic and constructive characteristics of capital equipment for growing hexapods and to find out demands which minimize technological cost price of its manufacture. **Methods.** Theoretical studies are lead on known procedure of parametric technical-economical analysis. As basic approach to solution of optimization problem they selected determination of ranges of values of technical parameters which minimize cost price without evaluation, actually, their values. At development of mathematical models the conjecture is accepted that monetary expenditures for materials and wages for manufacture of certain device are considered directly proportional area of its envelopment or length of its ridges. **Results.** Technical-economical analysis of capital equipment for growing hexapods (cells and boxes) for the purpose of determination of their optimum squares for minimization of technological cost price of manufacture of the equipment is lead. Mathematical model of cost price of manufacture of the equipment as function of geometrical sizes of cell and box is developed. For minimization of the specified cost price independent parameters on which optimization is carried out are selected, namely: amount of cells in a box, effective area of one cell, gross area of a box. All other parameters are regulated by technical requirements and are considered set. Model study shows that inside the set range of squares the objective function has no extreme, as in the specified range its first derivative always negative (it is not equal to null). Therefore the extreme (minimum) is attained only on boundary of the set range of squares, that is at peak figures of squares of cell and box. **Conclusions.** Cost of equipment, which is evaluated through technological cost of its manufacture, will be minimum at the greatest possible values of squares of cell and box. Limitations of these values will depend on technical requirements: ergonomics, strength, etc. At increase of sizes of cell from 25x25 cm up to 25x50 cm the reduced expenditures on materials for manufacture drop on 6%, and on payment — on 25%. At increase of productivity on 62% technological cost price of complex is drops on 2%. Approaches justified in study essentially improve economic indicators of complex.

Keywords: *growing of hexapods, equipment, model of technological cost price, optimization of square of cell.*

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In recent years ITI "Biotechnics" NAAS has created a number of technological complexes of mass breeding of entomophages [1] for use in programs of biological protection of plants from pests, as well as accumulated experience of their transfer, which determined the need for further improvement of equipment in the direction of improving economic efficiency.

The basic biotechnological requirements established in our previous researches [2], can be realized in various constructive decisions manufacturing of the equipment. Accordingly, the technical and economic indicators will change and it becomes possible to optimize technical solutions on the criterion of economic efficiency.

Analysis of recent research and publications. Technical and economic analysis (TEA) of project solutions [3, 4] - is a study of the relationship between technical, organizational and economic parameters and indicators that allows to find the best project solution for the selected criterion. So, the basic premise of TEA is the possibility of alternative solutions, and the task of TEA is to provide the best solution in the selection of equipment construction, manufacturing technology and other factors.

The analysis and generalization of technical characteristics of industrial samples of technological complexes for the production of trichogram, poachers, gold points, which was created in Ukraine, Russia, Uzbekistan [5, 6] shows that each stage (or several stages) of ontogenesis of insects proceeds in a certain capacity, the so-called, head (hereinafter referred to as TS). Head in quantity n_c placed in the technological box (shelves, containers, cabinets) (hereinafter TA), their number n_a is determined by a given performance Q a set of head and boxes at this stage of ontogenesis:

$$Q = n_a \cdot n_c \cdot W \cdot S_c = n_a \cdot n_c \cdot Q_c = W \cdot S, \qquad (1)$$

where S – total area of insects occupancy, m^2;

W – surface density of insects in head, individuals/m^2;

S_c – working head area, m^2;

$Q_c = W \cdot S$ – productivity of one head, individuals / head.

For entomological production, as established by our previous studies [7, 8], the determining biotechnological indicator is the surface density of insects W, which for the selected breeding process is a constant. It can be seen from expression (1) that a given performance can be assured at different values S_c, n_a, n_c. Optimization of the ratio of these factors is advisable by means of technical and economic analysis.

For any insects in existing developments, the maximum size of any head (cassettes, etc.) does not exceed about 0.5 m, and the height of the shelves - 1.5 m. It indicates that the main requirement in the construction of equipment was the actual provision of convenience of the staff in the laboratory with desks and the production of small samples, rather than improving the technical and economic performance of industrial production, and determined the relevance of the proposed article.

At equipment modernization the definition of economic efficiency is most often carried out through technological cost price of manufacture process[9]. This method of calculating economic efficiency is used when introducing any innovations in the existing technological processes, when the cost calculation is not carried out, but is limited only to comparing the options for variable operations.

Purpose of research – determine the relationship between the economic and structural specifications of the main insect containment equipment and find requirements that minimize the technological cost of manufacturing the equipment.

Research Methods. Theoretical studies of the implementation of the known method of parametric technical and economic analysis [9]. The main approach to the solution of the optimization problem was chosen to determine the ranges of technical parameters values that minimize the cost of production, without actually calculating the cost of production. When developing mathematical models, it is assumed that the monetary costs of materials and wages for the manufacture of a particular device are considered to be directly proportional to the area of its envelope or the length of its ribs.

Research results. When comparing all the components of the cost of manufacturing process equipment that depend on its construction, it is possible to estimate the technological cost of manufacturing equipment K [9], which is reduced to a conditional unit of production, namely:

$$K = (M + T + E), \qquad (2)$$

where M – cost of materials;

T – salary costs;

E – energy costs.

All costs are also reduced to the unit of production - UAH / Peculiarity. We consider other cost items to be constant, therefore, they do not affect the change in the cost of production from the selected input factors.

Energy costs at the project stage can only be determined through communication coefficients with other cost items. Experience has shown that energy costs *E* can be considered proportional to the amount of work from which:

$K = M + k\,T$, (3)

where *k* – a cost-recalculation factor, which will be considered constant for each equipment option.

Determine the main dependencies between the economic and technical parameters of the equipment. The following biological requirements are set [10]: h_c – head height, m; *W* – surface density of insects, individuals / m^2. From the technical specification is given *Q* – set performance. Equations linking head and box construction characteristics:

$$V_c = S_c \cdot h_c, \qquad V_a = \frac{n_c \cdot V_c}{\eta} = \frac{n_c \cdot V_c}{\eta_s \cdot \eta_h} = \frac{n_c \cdot S_c \cdot h_c}{\eta_s \cdot \eta_h} = S_a \cdot h_a, \qquad (4)$$

where V_c, V_a – working volume of head and box accordingly;

$= {}_s\ .\ {}_h$ – horizontal and vertical headbox filling ratio;

h_a, S_a – height and cross-sectional area of the box (shelf and floor area under the box).

From the given set of parameters we will choose independent – S_c, S_a, n_c, that can be changed for optimization. TS and TA heights– h_c and h_a is accordingly also independent, but has constructive limitations and will be further considered as a technical requirement.

The parameter to be optimized (minimized) was chosen as the technological cost of production of the set of head and boxes, which, taking into account (3), looks like:

$$K = K_c + K_a = \left(M_c + k_c \cdot T_c\right) \cdot n_c \cdot n_a + \left(M_a + k_a \cdot T_a\right) \cdot n_a, \qquad (5)$$

where are the indexes *c* and *a* denote the head and box parameters accordingly.

Thus, the obtained expression (5) is a mathematical model of production cost of the entomophages industrial production complex.

Next, we will build a mathematical model of the cost of manufacturing the head. Head is a closed volume, which contains insects at different stages of ontogenesis. It is made of plastic or metal, has a shell, bottom, removable lid. Body shape - parallelepiped or cylinder with height h_c, area of the base S_c, which, for simplicity, is considered to be a square on the length of the side $\ell_c = \sqrt{S_c}$.

In the model, the transition from physical parameters to cost parameters is carried out through the proposed coefficients of conversion of geometric parameters of a certain *j*-detail into the cost, based on certain assumptions:

m_{1j} – a coefficient of material value of the part, assuming that it is proportional to the surface area of the part, UAH / m^2;

u_{1j} – the coefficient of the total cost of wages, which is proportional to the area of detail, UAH / m^2;

u_{2j} – the coefficient of the total cost of wages, which are proportional to the perimeter of the part or to the double length of all edges for the construction in the form of a parallelepiped, UAH / m.

Costs of head materials that are proportional to the area of its lateral surface will be equal to:

$$M_c = m_{1c}\left(2S_c + 4\ell_c \cdot h_c\right) = m_{1c}\left(2S_c + 4h_c\sqrt{S_c}\right). \qquad (6)$$

Labor costs will be estimated proportionally to the double length of all the edges of the body, which is carried out by sharp workpieces, their gluing (welding) or bending, mechanical fixation, etc.:

$$T_c = 2u_{2c} \cdot \left(8\ell_c + 4h_c\right) = 2u_{2c} \cdot \left(8\sqrt{S_c} + 4h_c\right). \qquad (7)$$

By dividing expression (7) by ($W \cdot S_c$) and substituting the obtained expression into the first summand of expression (5) we get (for the head):

$$K_c = \frac{2m_{1c}}{W} + \frac{1}{W \cdot \sqrt{S_c}}\left(4h_c \cdot m_{1c} + 16u_{2c} \cdot k_c\right) + \frac{8h_c \cdot u_{2c} \cdot k_c}{W \cdot S_c}. \qquad (8)$$

The next step is to build a mathematical model of the cost of manufacturing the box (racking). The boxing consists of two parts: a shell and a floor or rail construction to accommodate the heads. Shape - parallelepiped with a conditionally square base.

Costs of cladding material that are proportional to the area of the cladding:

$$M_{аб} = m_{1б}\left(2S_a + 4h_a \cdot \ell_a\right), \qquad (9)$$

Where $\ell_a = \sqrt{S_a}$ – the length of the side of the base.

Labour costs for the shell, which are proportional to the double length of the ribs:

$$T_{аб} = 8u_{2б}\left(2\sqrt{S_a} + 4h_a\right). \qquad (10)$$

Costs of shelf construction material:

$$M_{ап} = m_{1п} \cdot n_h \cdot S_a = \frac{\eta_h \cdot m_{1a} \cdot h_a \cdot S_a}{h_c}. \qquad (11)$$

Labor costs for the shelf construction:

$$T_{ап} = u_{1п} \cdot n_h \cdot S_a = \frac{u_{1п} \cdot h_a \cdot \eta_h \cdot S_a}{h_c}. \qquad (12)$$

By dividing each of the expressions (9) - (12) into $(\eta \cdot W \cdot S_a)$ and substituting the expressions in the second addition of expression (5) we will have (for box):

$$K_a = \frac{2m_{1a} \cdot h_c}{W \cdot \eta \cdot h_a} + \frac{m_{1п} \cdot \eta_h}{W \cdot \eta} + \frac{u_{1п} \cdot k_a \cdot \eta_h}{W \cdot \eta} + \frac{1}{W \cdot \eta \cdot \sqrt{S_a}} \cdot \left(4m_{1a} \cdot h_c + \frac{16u_{2a} \cdot h_c \cdot k_a}{h_a}\right) + \frac{8u_{2a} \cdot h_c \cdot k_a}{W \cdot \eta \cdot S_a}. \qquad (13)$$

Thus, the production cost model of the set of head and boxes (5) taking into account (8), (13) can be presented in general:

$$K = a_c + \frac{b_c}{\sqrt{S_c}} + \frac{d_c}{S_c} + a_a + \frac{b_a}{\sqrt{S_a}} + \frac{d_a}{S_a}, \qquad (14)$$

where a_c, b_c, d_c, a_a, b_a, d_a – constant coefficients, which can be determined from formulas (8) and (13).

An analysis of this model shows that it is within a given range of area values S_c, S_a that is, on terms:

$$S_{\min} \le S \le S_{\max}, \qquad (15)$$

function (14) does not have an extremum, its first derivative is always negative (not equal to zero), so the minimum value of prime cost K will be at the range boundary, i.e.:

$K(S_c, S_a)$ = min, while $S_c = S_{c\,\max}$ and $S_a = S_{a\,\max}$. (16)

The last ratio proves the economic expediency of increasing the area of the head and the box (shelf) to the maximum possible values and was used in the modernization of the complex for the production of gold points usual, developed in the Institute of Engineering and Technology "Biotechnics" NAAS in 2008 [2]. This so-called basic complex uses 25 25 cm heads. (Position 3). Experimental studies with insects have confirmed the possibility of increasing the size to 25 50 cm (item 4). The figure also shows the heads (positions 1 and 2) used in laboratory studies of lacewing.

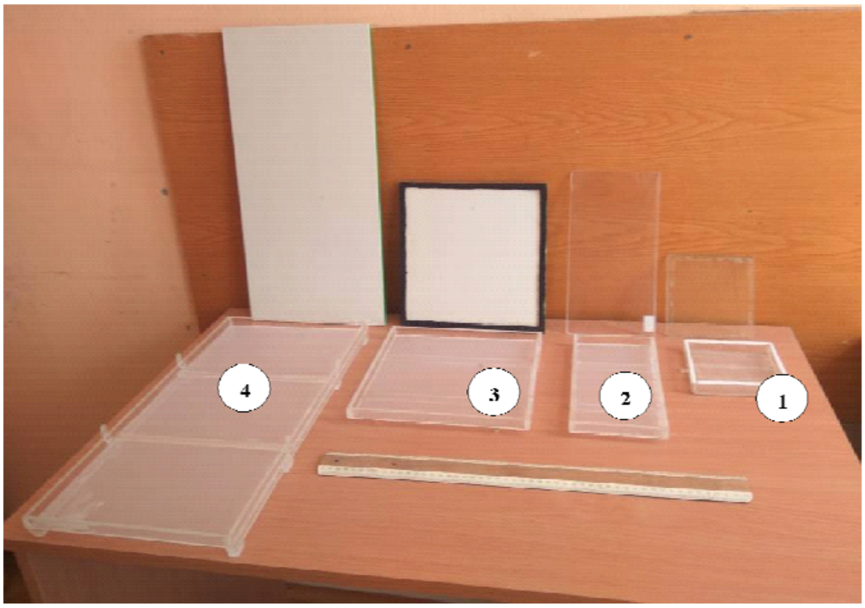

Fig. Experimental simulation of the head
to reduce their production costs.:
1, 2 – heads for laboratory tests; 3 – head base 25   25 cm; 4 – head upgraded 25   50 cm

By increasing the size of the head from 25   25 cm to 25   50 cm, the given material costs are reduced by about 6%, and wages by 25%. On this basis, a new technological complex TKZ-4.2 has been developed, which comparative indicators are shown in the table below.

With an increase in productivity of 62%, the technological cost of the new complex decreases by about 2%.

In the development of the new racking, an increase in the filling factor of   and the height h_a according to (13) were also used. This allowed to significantly reduce the required production area for the complex (Table), which reduces the operational costs of insect breeding by up to 2 times.

Comparative indices of complexes

Indicators	Basic 2008	New TKZ-4.2
Productivity per cycle, million eggs	11,25	19,2
Number of heads, pcs.	105	80
Number of racks, pcs.	3	2
Floor area under the equipment, m^2	4,1	2,95
Area of production site, m^2	15	7,5

Conclusions

The mathematical model of determination of the cost price of industrial production of equipment for production of entomophages as a function of the geometric dimensions of the head and boxing is constructed.

Analysis of the mathematical model shows that the cost of equipment, which is estimated through the technological cost of its manufacture, will be minimal at the maximum values of the head and box area. Limitations on these values will be imposed by such technical requirements, namely: ergonomic, strength and others. Calculations show that when the head is increased from 25   25 cm to 25   50 cm, the given costs of materials for manufacturing are reduced by 6%, and for wages - by 25%. With an increase in productivity of 62%, the technological cost of the complex decreases by 2%. Experimentally confirmed by the example of the usual lacewing cultivation that the reasonable approaches significantly improve the economic performance of the complex.

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