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DEVELOPMENT OF A STRUCTURAL-FUNCTIONAL MODEL OF A SINGLE PRODUCTION PROCESS OBTAINING SEED MATERIAL IN FARMS

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ABSTRACT

The questions of improvement of processing of seeds quality are very urgent now. But harvesting by modern methods doesn't allow reaching quality grain material. The mathematical description of process of processing of grain has been carried out. The Uniform process of receiving qualitative seed material has been made. The flowchart and software package was developed for the solution of this problem.

Keywords: seed material, seed traumatizing, lotka-volterra method, proni's method.

1. INTRODUCTION

The problem of development of a complex way of improvement of the seed material quality in system of technological processes of receiving grain and in offices of cars of harvest and postharvest processing of grain arises because of decrease in productivity of the sowed cultures. Any scientific research of definition of an optimum combination of cars, their operational and technological parameters in the "harvest-postharvest processing grain on seeds" system at all variety of combine harvesters and the grain-cleaning devices is absent. There is a need of consideration of functioning of all cars for uniform production for the purpose of receiving in farms of qualitative seed material with the minimum prime cost.

Questions of improvement of the seed material quality, during it's of reproductions of various types, at the existing technologies of harvest and postharvest processing of grain, on the used material equipment is an urgent problem at the moment.

Receiving qualitative seed material on the basis of the existing standard technologies and means of mechanization is a complex multicriteria challenge with a research of various multilevel objects. There is a need of formation and optimization of a stream of the movement of grain in the course of harvest, reloading and postharvest works that at the exit to have qualitative sowing material.
The solution of this problem can consist in formation of system of organizational and technological, technical and production actions. Creation and the subsequent realization of various types of models (mathematical, functional, economic, etc.) an object of researches of uniform production of receiving qualitative seed material is necessary. It is necessary to investigate each system or operation and to optimize each stage of change of quality of seeds, shares of his exit cost of receiving within any type of the agricultural commodity producer.

The available experience shows that many farms allocate sites of reproduction from land fund and, buying super elite, reproduce it and sow seeds of the first, second and third reproduction. The matter has economic character. Farms have no specialized seed-production equipment. All technological operations connected with cleaning, postharvest processing, by an overload and storage of grain it is carried out with use of standard means of mechanization at standard (tabular) operating modes. Because of it at the exit seeds, sub-standard on purity (to 35%), with a large number of macro- and microdamages, with a big variation of their dimensional and cost characteristics turn out. These indicators reduce sowing qualities of seeds that leads to a harvest shortage (on average on an indicator of quality of purity of seeds loss of a harvest from 4 to 6 c/hectare, is the share of a traumatizing from 5 to 8 c/hectare, fractional structure from 3 to 5 c/hectare). Besides, process of receiving seed material directly in farms isn't considered as the uniform closed production: "cleaning - an overload - postharvest processing grain". For this reason improvement of quality of seeds is considered separately for each technological operation.

The complex approach to development of technology, means of mechanization of this technology and modernization of the operative equipment which is capable to increase indicators of quality of the received seeds is absent. Search of ways of increase in qualities of seeds which influence to crops sowing is required:

- decrease in a macro and micro traumatizing;
- receiving the seeds set by the sizes of fraction;
- increase in purity of the sowed seeds.

The following decisions will be required.

a) Structural optimization of the operating technical means which provide process of cleaning, transportation, postharvest processing of grain.

b) Formation of groups of cars within separate technologies.

c) Parametrical optimization of operating modes of machines and units.

d) Modernization of means of mechanization and the equipment which work within the chosen technology.

e) Application of new fractional schemes of cleaning in technological operations of postharvest processing of grain.

f) Performance of agro-technical terms within each technological operation.

The existing technologies of receiving grain have a wide choice of means of mechanization which form various indicators of quality of grain and its prime cost at the exit. There is a discontinuity of processes of cleaning, postharvest processing of grain, reloading works that doesn't allow receiving qualitative seed material in farms at its minimum cost.

The main of an integrated approach for definition of an optimum combination of cars, their technological parameters in uniform production of receiving seeds can become structurally functional modeling. It will allow to obtain the maximum information on change of quality indicators of seeds both separate technological operations, and systems in general, and also to become a software basis.

2. MATERIALS AND METHODS

The Lotka-Volterra method is used for the description of structurally functional model of processing of a grain part of a harvest of grains of cultures. By means of this method the general system of the differential equations has been made and adapted. In a mathematical form the model of system can be described by the following system:

$$\begin{cases} \dot{\tilde{Q}} = a\tilde{Q} - b\tilde{Q}_1\tilde{R}; \\ \dot{\tilde{R}} = -c\tilde{R} + d\tilde{Q}_1\tilde{R}; \\ \dot{\tilde{Q}} = e - z\tilde{Q}_2\tilde{H}; \\ \dot{\tilde{H}} = -k\tilde{H} + r\tilde{Q}_2\tilde{H}; \end{cases}$$

where

$\tilde{Q}(t)$ is the volume of the general grain and haulm material during cambine cleaning (ton);

$\tilde{Q}_1(t)$ is volume of frumentaceous (ton);

$\tilde{R}(t)$ is the volume of the cleaned grain in timepoint t (ton);

$\tilde{Q}_2(t)$ is the volume of not grain part of the grain cultures harvest which arrives for processing from the field (ton);

$\tilde{H}(t)$ the volume of the processed not grain part of the grain cultures harvest in timepoint t (ton);

$a > 0$ is productivity of frumentaceous cleaning;

$c > 0$ is the total volume of in frumentaceous impurity (it's considered as a vector of entrance influences);

$b > 0$ and $d > 0$ are parameters which describe efficiency of purification of grain of impurity (the complex indicators influencing indicators of quality of process);

$e > 0$ is productivity of processing of haulm fraction in a final profitable product;

$r > 0$ is total indicator which characterizes of haulm material properties taking into account various fractions and impurity in initial weight (it's considered as a vector of entrance influences);

$z > 0$ and $k > 0$ are the parameters describing efficiency of processing of haulm fraction in a final profitable product.

The adapted Proni's method was applied to the solution of system of the equations of the Lotka-Volterra system of equations and to specification of parameters of model. It is a method of approximation of selective data with the help of the final sum of complex exponential functions (exhibitor). This method restores model parameters in which the analysis of skilled data, calculations, deviations and bandages is carried out.

Approximation of data with use of the determined exponential model of a grain part of a harvest is carried out by means of Proni's method.

Interpolation of these taken measurements has been carried out by Proni's method which is based on adjustment of exponential model to the measured equidistant values and the subsequent calculation of additional values by means of estimation of parameters of this exponential model in intermediate points. The adapted Proni's method which has been received by means of a method of the smallest squares in many respects is based on the initial Proni 's procedure.

Proni has described a method of exact adjustment which is based on use of such large number completely fading an exhibitor how many they are necessary for approximation of N available points of data (skilled data). The adapted option of a Proni's method is generalized also on model. In it model option the analysis by a method of the smallest squares for approximate adjustment of exponential model in those subsystems when the number of points of data exceeds their number necessary for adjustment by means of estimated number of exponential functions is also used.

3. EXPERIMENTS

Uniform process of receiving qualitative seed material in farms can be described the generalized block

diagram of consecutive operations of production of commodity grain (Figure-1). The generalized economic parameter can be as function of the purpose

$$F = f(P_j ... P_n), \quad (0)$$

which considers product cost, costs of production and the got profit on use of this system[1, 2].

The set indicators of quality of seeds both on leaving the system and within each technological operation will be restrictions.

It is necessary to pass to consideration of these technological operations from a position of subsystems.
The cleaning system is understood as initial characteristics of a harvest, and also cleaning operation which are carried out by combine harvesters on various technologies.

The system "transport-reloading" is understood as characteristics of grain material of a past cleaning, and also all operations of shipping and reloading works which are performed by machines.

The "postharvest processing of grain" system is understood as characteristics of grain material after transport and loading works, operation of postharvest processing of grain in offices the grain-cleaning devices and technological cleaning machines.

"The mathematical model of system" of receiving qualitative seed material is understood as system of the interconnected equations which describe both functioning of system in general and her separate operations with the subsequent its optimization by the set criteria taking into account the accepted restrictions.

As criterion of optimization and system of receiving qualitative seed material in farms the following indicators are accepted: purity of seeds, viability, fractional structure, a complex indicator of seed macro - and mikrotraumatizing, cost of production, annual economic effect and economic effect of updating of grades.

The generalized total indicator of seed traumatizing is defined as

$$T_{\Sigma tr} = \frac{D_{nucl} + D_{end} + D_{n.e.c.} + D_{e.c.} + D_{macro} + D_{w.d.}^{-1}}{n} \quad (1)$$

where

D_{nucl} is a nucleus damage;
D_{end} is anendosperm damage;
$D_{n.e.c.}$ is a damage of the germ and endosperm cover;
$D_{e.c.}$ - is a damage of the endosperm cover;
D_{macro} is the macro-damaged grains;
$D_{w.d.}$ is the percent of seeds without damages;
n - the quantity of the used indicators.

The fractional composition of the sowed material is defined by distribution density *f(i)* - sizes of a sign of division of seeds. For wheat a sign of division is grain thickness *(b)=>f(b)*[3,4].

$$\lim \frac{F(b+\Delta b) - F(b)}{\Delta b} \quad (2)$$

where
b - grain thickness in selection, mm;
Δb - average value of size in selection, mm.
Absolute profit [5].

$$P = C_1 - C_2, \text{ rub.}, \quad (3)$$

where
C_1 - the cost of the made production in the strike prices, rub.,
C_2 - the cost of the made production reflecting cumulative expenses in fixed assets, current assets and manpower for introduction of new technologies, rub.
Profit margin [5].

$$P_m = \frac{100P}{C_2}, \text{ rub.} \quad (4)$$

The received size has to be not below effectiveness ratio of investments which is equal to an interest rate for the credit which is established by the central bank of the Russian Federation increased by coefficient of a guarantee of obtaining positive effect.

Primary cost Pc of production of agricultural production is calculated by a formula [5]:

$$P_c = \frac{P_F + P_R + P_T + O_c}{y}, \text{ rub/ton}, \quad (5)$$

where factor operational cost I_F calculates according to GOST 23730 and standard reference materials, and the cost of material resources of *Ir* - on a formula:

$$C_R = Q_i \cdot C_i, \text{ rub/g.} \quad (6)$$

Overhead costs O_c calculate according to actual data of economic subjects of various forms of ownership with the subsequent their standard account in technological cost of production of agricultural raw materials, finished goods: on branches (crop production, livestock production, processing) - in proportion to the gross output in rubles, on cultures - in proportion to the power means spent for their production transferred to conditional reference hectares.

Annual labor input A_{LI} of production of the production agricultural:

$$A_{LI} = \Sigma \frac{Л_i}{W_{смi}} F_i. \quad (7)$$

Payback period of capital investments in the equipment, technology:

$$P_P = \frac{K}{P_B} \text{ years,} \tag{8}$$

where capital investments K on the planned amount of works from use of:

$$K = \Sigma B_i \cdot N_i, \tag{9}$$

and balance profit:

$$P_B = (P_R - P_c), \text{ rub.} \tag{10}$$

Economic effect of application of the reproduced seeds in farms on new technology develops due to increase in an exit of production from unit of area and improvement of her quality, and also change of costs of their introduction in comparison with the seeds received on standard technologies. Annual economic effect is determined by a difference of net income from 1 hectare between the seeds received on the new and basic technology increased by acreage by seeds received on new technology:

$$E_{year} = (NP_{new} - NP_{base}) \cdot A_{new} \tag{11}$$

where NP_{new}, NP_{base} is the net price from seeds received on new and basic technology respectively in a new way and basic to grades, A_{new} is anacreage seeds of new technology.

For detection of economically reasonable need for seeds of elite and the subsequent reproductions of crops, including grain, it is offered to apply coefficient of economic efficiency of a sortoobnovleniye or sortosmena which is defined by the relation of the discounted gain of net income in the planned period (several years) to the discounted costs of updating of grades (change of grades):

$$K_{ES} = \frac{\Sigma \frac{(NP_{new} - NP_{base})}{(1+r)^t}}{\Sigma \frac{C_{change}}{(1+r)^t}} \tag{12}$$

where C_{change} is cost of change of grades or updating of grades (acquisition of elite seeds).

For the description of structurally functional model of processing the Lotka-Volterra method by means of which the general system of the differential equations is made and adapted is used. In a mathematical form the model of system can be described by the following systemıo Phase changes of a product in the course of cleaning:

$$\dot{Q} = a\dot{Q} - b\dot{Q}\dot{R} \tag{13}$$

$$\dot{R} = -c\dot{R} + d\dot{Q}\dot{R}$$

where

$(\dot{Q})t$ is the complex volume of the general grain of haulm material during receiving seeds of commercial farm unit.

$(\dot{R})t$ - is the complex volume of the seed material in the period of agrocycle t.

where

a is characterizes the general productivity of cleaning;

b is a parameter which describes efficiency of processes of harvesting and postharvest processing of grain;

c is characterizes an initial state harvested (a vector of output influences);

d is a parameter which describes efficiency of processes of harvesting and postharvest processing of grain;

$$\begin{cases} \dot{Q} = (Q_I, Q_{II}, Q_{III}, ..., Q_n) R_+^q; \\ R_+^q = \{Q \in R^n; Q \geq 0\}. \end{cases} \tag{14}$$

where $Q_I, Q_{II}, Q_{III}, ..., Q_n \geq 0$. The vectors $Q_I, Q_{II}, Q_{III}, ..., Q_n$ designate phase changes of frumentaceous.

For the formal description of dynamic system with continuous time during which there is a modeling of dynamics of process of phase changes of seeds in a stream of technological operations of cleaning and processing of grain.

Dynamics of the isolated process of receiving seeds will be defined by the differential equation: $Q = Q_n \cdot f_n(Q)$, where Q_n is the volume of grain lots of the technological process arriving on n-th operation in timepoint of t;

$f_n(Q)$ is functionality which depends on quality and quantitative indices of grain lots on n-thoperation.

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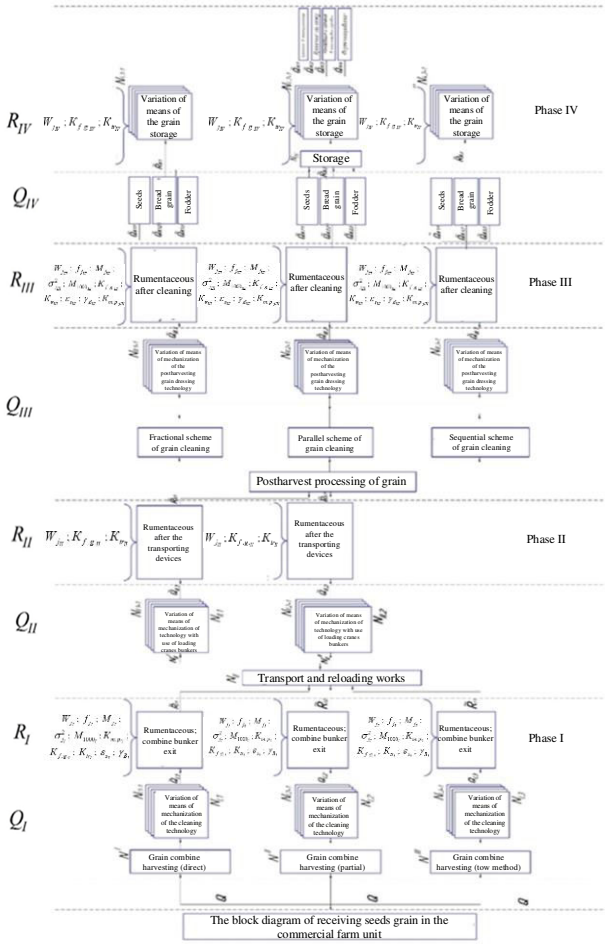


Figure-1. The block diagram of receiving seeds grain in the commercial farm unit.

We will describe submodels of processing of grain lots and transition of quality and quantitative indices (phase changes of products) on n-technological operation. Phase changes of a product in the harvest process:

$$\begin{cases} \dot{Q}_I = a \cdot Q - b Q_I R_I \\ \dot{R}_I = -c \cdot R + d Q_I R_I \end{cases} \tag{15}$$

where $Q_I(t)$ is the volume of grain which turns out in the course of the harvesting.

Phase changes of a product in the course of transport and reloading works.

$$\begin{cases} \dot{Q}_{II} = a \cdot Q_I - b Q_{II} R_{II} \\ \dot{R}_{II} = -c R_I + d Q_{II} R_{II} \end{cases} \tag{16}$$

where $Q_{II}(t)$ is thegrain volume in the course of transport and reloading works.

Phase changes of a product in the course of post harvest processing of grain.

$$\begin{cases} \dot{Q}_{III} = a \cdot Q_{II} - b Q_{III} R_{III} \\ \dot{R}_{III} = -c R_{II} + d Q_{III} R_{III} \end{cases} \tag{17}$$

where $Q_{III}(t)$ is the volume of seeds which turn out after grain cleaning.

Phase changes of a product in the course of grain storage.

$$\begin{cases} \dot{Q}_{IV} = a \cdot Q_{IV} \\ \dot{R}_{IV} = -c R_{IV} \end{cases} \tag{18}$$

where $Q_{IV}(t)$ is the volume of seeds in the course of it's storage.

Considering system (14) as mathematical model, it is natural to consider phase space a set

$$R_+^2 = \left\{ Q, R : Q \geq 0, R \geq 0 \right\},$$

which is invariant as any path which beginning in R_+^2 can't cross the lines $Q = 0$ and $HR = 0$ which are phase curves.

The dimensionless variable systems take a form:

$$\begin{cases} \dot{Q} = Q(1 - R) \\ \dot{R} = lR(Q - 1) \end{cases} \tag{19}$$

The system (21) has two motionless points: (0, 0), (1, 1). The standard linear analysis shows that a point (0, 0) - a saddle (Figure-2). Corresponding to indicators of quality of the initial cleaned material in the field.

Phase changes of seeds grain-0 (an initial state harvested).

W_j	is humidity (further in the text $W_{j\,I,II,III,IV}$– humidity which corresponds to phase change of a product);
$\varepsilon_з$	is frumentaceous contamination in relative units;
f_j	is elementary probability law;
M_j	is mean of distribution of the j-th size;
σ_j^2	aredispersions;
γ_B	is frumentaceous density, kg/m^3;
M_{1000}	is a mass of 1000 grains;
$K_{f.g.}$,	% is a growth force, a laboratory germination, a field germination;

$K_{m.p.}$, % is the complex indicator of morphological properties of seeds;

K_{tr} is the complex coefficient of a seed traumatizing, (damage of a germ, endosperm, grain macro damage, amount of grains without damages).

Phase changes of a product - I (the grain material after combine cleaning).

$$W_{j_I};\ f_{j_I};M_{j_I};\sigma^2_{j_I};M_{1000_I};K_{m.p._I};$$

$$K_{f.g._I};\ K_{tr_I};\ \varepsilon_{з_I};\ \gamma_{B_I}.$$

Phase changes of a product - II (the grain material after transporting and loading works).

$$W_{j_{II}};K_{f.g._{II}};K_{tr_{II}};\gamma_{B_{II}}.$$

Phase changes of a product - II (the grain material after postharvest processing of grain).

$$W_{j_{III}};\ f_{j_{III}};M_{j_{III}};\ \sigma^2_{j_{III}};M_{1000_{III}};K_{f.g._{III}};$$

$$K_{tr_{III}};\varepsilon_{з_{III}};\ \gamma_{B_{III}};K_{m.p._{jIII}}$$

Phase changes of a product – IV (storage of the grain material).

$$W_{j_{IV}};K_{f.g._{IV}};K_{tr_{IV}}$$

N+1 – way of the garin movement which is caused by *n*-th changes of a product condition.

The state space R^2_+ isgeneral set of a variation of receiving seeds in the general production technology of grain, two-dimensional space is filled with the closed trajectories to which periodic decisions answer.

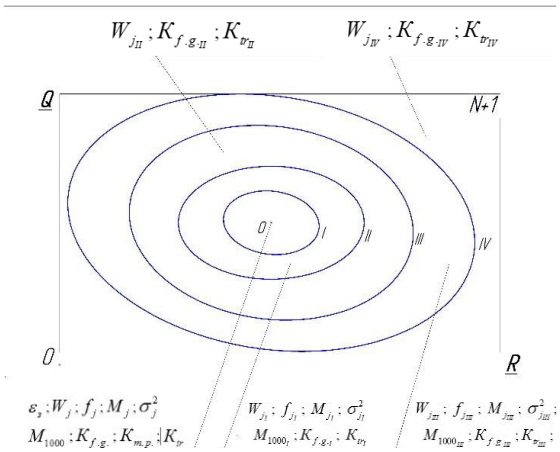


Figure-2. Phase portrait of system.

The phase portrait of system is described by integrated curves of the equation:

$$\frac{dh}{dq}=l\frac{h(q-1)}{q(1-h)}, \tag{20}$$

which common decision

$$lq+h-\ln qh=D, \tag{21}$$

where $D > D_{min} = 1 + l$,

D is the final volume of qualitative seed material;

D_{min} is function $H(q,h)$ minimum which is reached in a point $q=1,\ h=1$;

D_{min} is the the volume of seeds which is necessary for the commercial farm unit needs.

That is the equation of private decisions (23) has an appearance for the following phase changes:

$$\begin{aligned}
&lq+h_1-\ln q_1h_1=D\\
&lq+h_2-\ln q_2h_2=D\\
&lq+h_3-\ln q_3h_3=D\\
&lq+h_4-\ln q_4h_4=D
\end{aligned} \tag{22}$$

Actually, $D_{qq}(1,1)=0$, $D_{hh}(1,1)=0$ и $D_{qq}(1,1)<0$, $D_{qh}(1,1)=0$, $D_{hh}(1,1)<0$. It is easy to check that $L_tD(q,h)=0$ and, therefore, function $D(q,h)=0$ sets the first integral of system. After the analysis of lines of level of function $D(q,h)$ it's possible to show that for any $D>D_{min}$they are the closed curves (Figure-2).

If number of complex exponents *p* is even-numbered then we have*p/2* the fading cosinusoids. If it is odd-numbere then we will have *(p-1)/2* fading cosinusoids and one completely fading exponent.

Frequencies are evaluated on the basis of the available data in Proni's method.

For the numerical analysis of the received results it is necessary to count a system discrepancy

$$\theta=\Sigma^9_{i=0}(N(t_i-N1_i))^2=643.903 \tag{23}$$

and also relative error

$$\theta=\sqrt{\frac{\Sigma^9_{i=0}(N(t_i-N(t_i)^2)^2}{\Sigma^9_{i=0}(N(t_i)^2)}}=0.22 \tag{24}$$

By the received results it is possible to make a conclusion that our model is adequate and describes structurally functional model of receiving qualitative seed material with high precision.

4. RESULTS

The algorithm is developed for the set model and its simplified flowchart including calculation of technological processes of cleaning, transportation, postharvest processing of seeds, storages is submitted (Figure-3). The received algorithm makes calculation of different options of harvesting with calculation of the main indices of the combine work, handling devices, diagrams of cleaning and productivity proceeding from figures of merit of the initial cleaned frumentaceous.

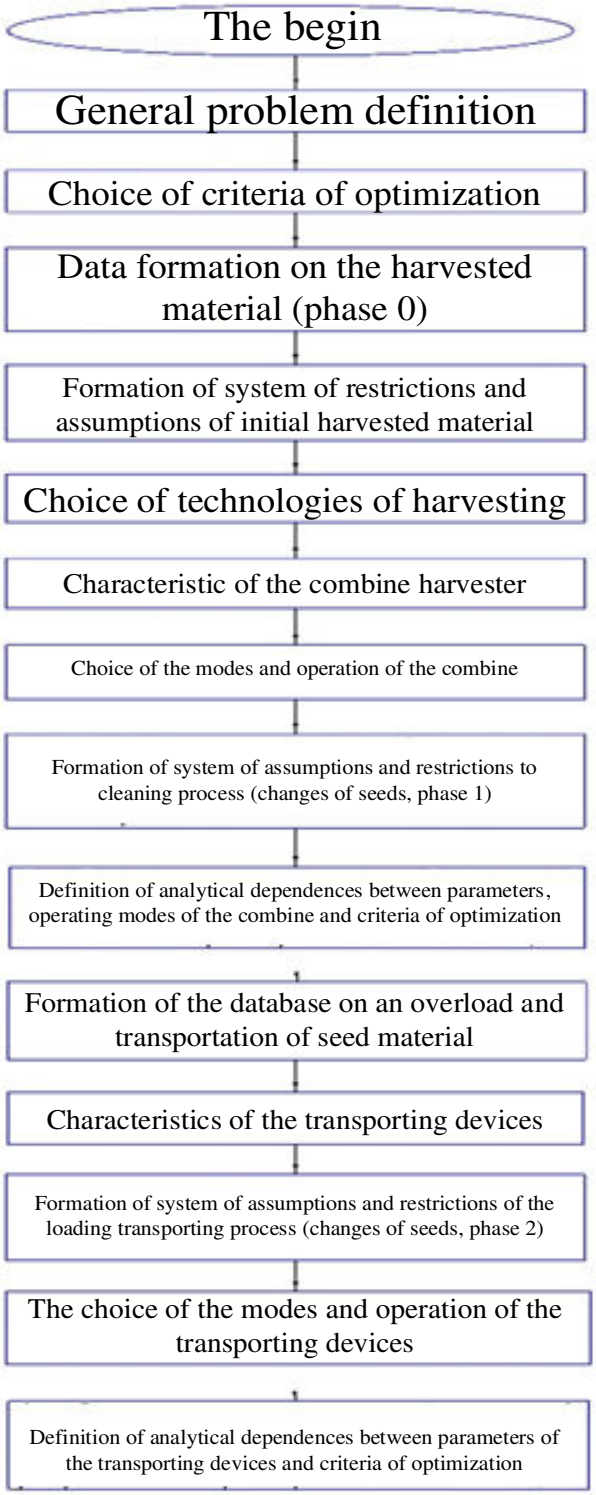
The mathematical model and algorithms of functioning of system of receiving qualitative seed material developed on its basis in the commercial farm unit are realized on a computer under control of Windows. As a development environment of the program language C ++ was selected. Reasons for a language C++ choice is that this programming language is used in most the IT companies and includes all necessary means which are necessary for implementation of an objective.

C++ is capable to work with databases, to create graphic interfaces, to make an output of graphic and text data to the screen with the subsequent printing on the printer. Thanks to the unique library C ++ it is capable to realize estimated operations quicker, than his competitors of Delphi and Python though concedes to Assembler, but for operation on Assembler it is necessary to have experience in the hardware programming. The main objects with which the program will work were selected at the first development stage. They included the files of databases, screen entry forms of the initial information, subprogrammes which are realizing: communication between the user and a computer via the graphic interface, calculation and formation of output data, an output to the screen and the printing of results of calculation.

File structure of input and output information, the documents describing subjects of databases: combines, cars, stationary points and total characteristics of diagrams of functioning of a complex it was formulated at the second stage.

In development process the decision on application of building block system was made. The following modules were a part of the program:

- graphic interface;
- module of technical and ecological reasons for combine cleaning;
- module of technical and ecological reasons for technological means of transport and loading operations;
- the module of calculation of the line of postharvest processing of seeds for the selected diagrams of cleaning;
- module of formation of the estimated text and graphic information;
- the module of formation of selections and record in corresponding for the selected technological complex, the directory and the file for formation of a graphic illustration of results of calculations.



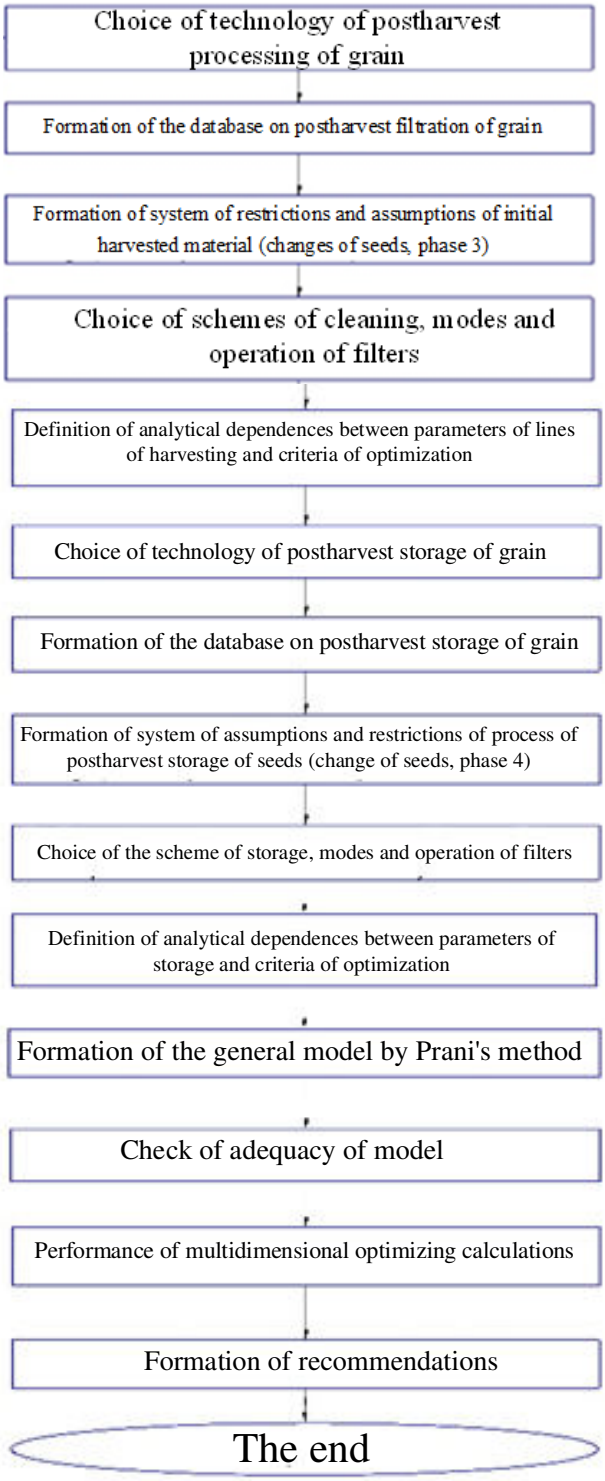


Figure-3. The scheme of an algorithm of model of functioning of system of the discharged seed material in the commercial farm unit.

5. CONCLUSIONS

The block diagram of "Uniform process of receiving qualitative seed material" (UPRQSM) which includes technological operations (subsystems) "combine cleaning", "loading transporting" "postharvest processing" with function of the purpose expressed by economic parameter (0), considering product cost, costs of production and the got profit of system in general has been made.

The determined structurally functional model which considers parameters of laws of distribution of private technological operations has been used for calculation of parameters of overall performance of the UPRQSM system. As economic criteria overall effectiveness, absolute profit and rate of return are applied. The general assessment of the "cleaning-postharvest processing" system is executed on set of phase indicators of quality of seeds of each subsystem (phase changes of a product in the process of the j-th technological operation). The general system of the differentiated equations by the Lotka-Volterra method which describe models of separate technological operations is received: the cleaning, postharvest processing, transport and loading works forming process of receiving seeds.

The structure and algorithm of the determined model of criterion function by definition of optimum structure of a complex of machines and their technological parameters for realization of model with use of Proni's method, and also for the analysis of technological processes of receiving grain in farms have been made: cleaning, transport and reloading works, postharvest processing of grain and all technology entirely.

Experimental check of the new determined structurally functional model of uniform production of harvest and postharvest processing of grain for the purpose of receiving qualitative seed material. This model reckoned with use of the adapted Proni's method and was checked for adequacy by means of system nonviscous $N(t_i)\text{-}N1_i)^2=643.903$and a relative error

$$\sqrt{\frac{\Sigma_{i=0}^{9}(N(t_i-N(t_i)^2)^2}{\Sigma_{i=0}^{9}(N(t_i)^2)}}=0.22$$

Experimental check has confirmed adequacy to the described model.

The flowchart and software package on the basis of the C# programming language was developed. The selected programming language allows selecting rational composition of mechanical means of ensuring of these technological processes and their parameters of operation for the specific enterprises, to evaluate finite indices of the received seeds and their prime cost.

To use the received structurally functional models of receiving qualitative seeds in case of determination of technologies and means of mechanization in the course of cleaning of grain crops of in the commercial farm units of the South of Russia.

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