ISSN 2073-7599 (print)
ISSN 2618-6748 (online)

Agricultural MACHINERY and TECHNOLOGIES

SEL'SKOKHOZYAYSTVENNYE MASHINY I TEKHNOLOGII

Tom 12 N3 2018

Vol. 12 N3 2018

NAUCHNO-TEORETICHESKIY ZHURNAL

SCIENTIFIC-THEORETICAL JOURNAL

CONTROLLING TECHNOLOGICAL PROCESSES IN CROP PRODUCTION

ASSESSING PERFORMANCE EFFICIENCY OF GRAIN COMBINE HARVESTERS

MICROPROCESSOR CONTROL SYSTEMS OF IRRADIATION INSTALLATIONS

Agricultural MACHINERY and TECHNOLOGIES

Founder and publisher: Federal State Budgetary Scientific Institution "Federal Scientific Agroengineering Center VIM" of the Russian Academy of Science

SCIENTIFIC-TEORETICAL JOURNAL

The journal is registered by Federal Agency for Supervision of Legislation Observance of Mass Communications Sphere and Cultural Heritage Protection Certificate ПИ No. ФС77-68608 from February, 3, 2017

The journal is included in the Russian Index of Scientific Citation (RISC).

Full texts of papers are available on the website of electronic library: elibrary.ru

Protected by the Russian Federal Law RF №5351-1 “On Copyright and Related Rights” dated July 9, 1993. Content is distributed under Creative Commons Attribution 4.0 License. Violations are subject to prosecution.

EXECUTIVE EDITORS:
Prokopovich E.V.,
Bizhaev V.V.,
Nurbagandova R.M.
Translation into English - Aleksei Alipichev

EDITORIAL OFFICE'S ADDRESS
109428, Moscow,
1st Institutskiy proezd, 5
Tel.: +7 (499) 174-88-11
+7 (499) 174-89-01
http://www.vimsmit.com
e-mail: smit@vim.ru

Printed by FSAC VIM
Russian Academy of Science
The format is 205 × 290 mm
The issue was submitted for printing on 15.06.2018
The circulation is 500 copies

EDITOR-IN-CHIEF

Andrey Yu. Izmaylov
Dr. Sc. (Eng.), Academician of the Russian Academy of Sciences, Academic Board Member of the Russian Academy of Sciences, Director of the Federal Scientific Agroengineering Center VIM, Moscow, Russian Federation

EDITORIAL BOARD

Viktor V. Al't
Dr. Sc. (Eng.), Professor, Academician of the Russian Academy of Sciences, Honoured Scientist of Russian Federation, Academician of NAS of Mongolia, Head of Scientific Division of Siberian Institute of Physics and Technology of Agrarian Problems, Novosibirsk, Russian Federation

Khristo. I. Beloev
Dr. Sc. (Eng.), Professor, Corresponding Member of the Bulgarian Academy of Sciences, University of Ruse, Republic of Bulgaria

Mikhail N. Erokhin
Dr. Sc. (Eng.), Professor, Academician of the Russian Academy of Sciences, Russian State Agrarian University – Moscow Timiryazev Agricultural Academy, Moscow, Russian Federation

Yuriy A. Ivanov
Dr. Sc. (Agr.), Academician of the Russian Academy of Sciences; Director of the All-Russian Scientific and Research Institute of Livestock Mechanization, Podolsk, Russian Federation

Ivan M. Kulikov
Dr. Sc. (Econ.), Professor, Member of the Russian Academy of Sciences, Director of the All-Russian Horticultural Institute for Breeding, Agrotechnology and Nursery, Moscow, Russian Federation

Yakov P. Lobachevskiy
Dr. Sc. (Eng.), Professor, Corresponding Member of the Russian Academy of Sciences, First Deputy Director of the Federal Scientific Agroengineering Center VIM, Moscow, Russian Federation

Yuriy F. Lachuga
Dr. Sc. (Eng.), Professor, Academician of the Russian Academy of Sciences, Academician Secretary of Department of Agricultural Sciences at the Russian Academy of Sciences, Moscow, Russian Federation

Antonin Makhalek
Dr. Sc. (Eng.), Director of the Agricultural Machinery Research Institute, Prague, Czech Republic

Tadeush Pavlovsky
Dr. Sc. (Eng.), Professor, Director of the Industrial Institute of Agricultural Machines, Poznan, Poland

Vladimir D. Popov
Dr. Sc. (Eng.), Professor, Academician of the Russian Academy of Sciences, Head of the Research Direction of the Institute of Agroengineering and Environmental Problems of Agricultural Production, St.Peterburg, Russian Federation

Zharylkasyn S. Sadykov
Dr. Sc. (Eng.), Professor, Director of Research Institute of Agroengineering Problems and New Technologies, Kazakh National Agrarian University, Almaty, Republic of Kazakhstan

Dmitriy S. Strebkov
Dr. Sc. (Eng.), Professor, Academician of the Russian Academy of Sciences, Federal Scientific Agroengineering Center VIM, Moscow, Russian Federation

Yulia S. Tsench
PhD (Ped.), Associate Professor, Head of Publishing Activity, Education and Technical information Department of the Federal Scientific Agroengineering Center VIM, Moscow, Russian Federation

Vyacheslav I. Chernoivanov
Dr. Sc. (Eng.), Professor, Academician of the Russian Academy of Sciences, Federal Scientific Agroengineering Center VIM, Moscow, Russian Federation

Sergey G. Yakovchik
PhD (Agri.), General Director of the Scientific and Practical Center of the National Academy of Sciences of Belarus for Agricultural Mechanization, Minsk, Republic of Belarus

CONTENTS

CC BY

DOI 10.22314/2073-7599-2018-12-3-4-11

Optimization of Technological Process Management in Plant Growing

Andrey Yu. Izmailov, Dr.Sc. (Eng), Member of the Russian Academy of Sciences, Director;
Yakov P. Lobachevsky, Dr.Sc. (Eng), Corresponding Member of the Russian Academy of Sciences, Chief Researcher;
Vyacheslav K. Khoroshenkov, PhD (Eng), Head of the Laboratory;
Igor G. Smirnov, PhD (Agri), Leading Reseacher;
Nikolai T. Goncharov, Senior Research Engineer;
Yelena S. Luzhnova, Research Engineer

Federal Scientific Agroengineering Center VIM, Moscow, Russian Federation. e-mail; vim-avt@rambler.ru

Abstract. At the current development stage of agricultural production, agricultural enterprises are faced with precedent pressure from the market. (*Research of purpose*) Optimize the control parameters of agricultural production by introducing the latest technologies, reducing costs and ensuring more efficient production management. (*Materials and methods*) The elaboration of a centralized unified automated information management system for mobile units and stationary processes incorporates the following components: Automation of the technological process with the possibility of locating every mobile machine, tractor, combiner harvester, any other vehicle, or fixed object in the field; Transferring integrated process parameters to the dispatch center server, transforming these parameters into a convenient form for technologists, agronomists, and managerial staff; Transferring control commands to adjust the process by its performers (operators). (*Results and discussion*) The authors have developed agricultural production systems of a new generation to ensure the productivity level of agrocenoses with high efficiency of invested funds and the use of landscape capacity. The basic prerequisite here is that the productivity of plants depends, first of all, on the soil content of mineral nutrients with their optimum ratio in each elementary field section, as well as a set of crop protection measures. (*Conclusions*) Increased production and cost reduction cannot be achieved without the introduction of the latest information-based automated control systems for production processes based on network technologies for gathering, collecting, analyzing relevant data and developing optimal management decisions. Especially important in agricultural production is the intensity rate of machinery utilization, as well as the line balance and consistency of manufacturing processes.

Keywords: means of automation, robotization and informatization, digital technologies, technological processes in field crop cultivation, agricultural machinery units.

For citation: Izmailov A.Yu., Lobachevsky Ya.P., Khoroshenkov V.K., Smirnov I.G., Goncharov N.T., Luzhnova Ye.S. Optimization of technological process management in plant growing. *Sel'skokhozyaystvennye mashiny i technologii*. 2018. 12(1): 3-9. DOI 10.22314/2073-7599-2018-12-3-4-11. (In Russian)

Agricultural production is characterized by a wide range of technological operations and technological tools to carry out field works [1]. To optimize production management, we should develop algorithms for a microprocessor multidimensional unified system that could be fully used, both on mobile devices and at stationary points for post-harvest processing and storage of agricultural products [2].

In the hardware and software packages, there is no difference in the maintenance of mobile or stationary objects. It all comes down to the processing of analogue, discrete or frequency information from the respective sensors, the transfer of control commands to the executing devices, and the transmission of integrated process indicators to the dispatch center server for further processing and archiving.

Research of purpose. The aim of the present research is to optimize the management of agricultural production by introducing the latest technologies, reducing costs and ensuring more efficient production management.

Materials and methods. The development of a centralized unified automated information system for controlling the work of mobile units and stationary processes includes the following aspects:

- automation of technological processs with linking the location of mobile units in the field, whether it is a machine-tractor unit, a combine harvester, a vehicle or a stationary object;
- transferring integrated technological parameters to the central office of the dispatch center, transforming these parameters into a form convenient for providing information to technologists, agronomists, or enterprise managements;
- passing control commands to adjust the process to actual performers.

Such system of control allows improving the organizational model of an enterprise, the structure of production and management units, the function of information processing, the development of managerial decisions, bringing them to performers, which ultimately

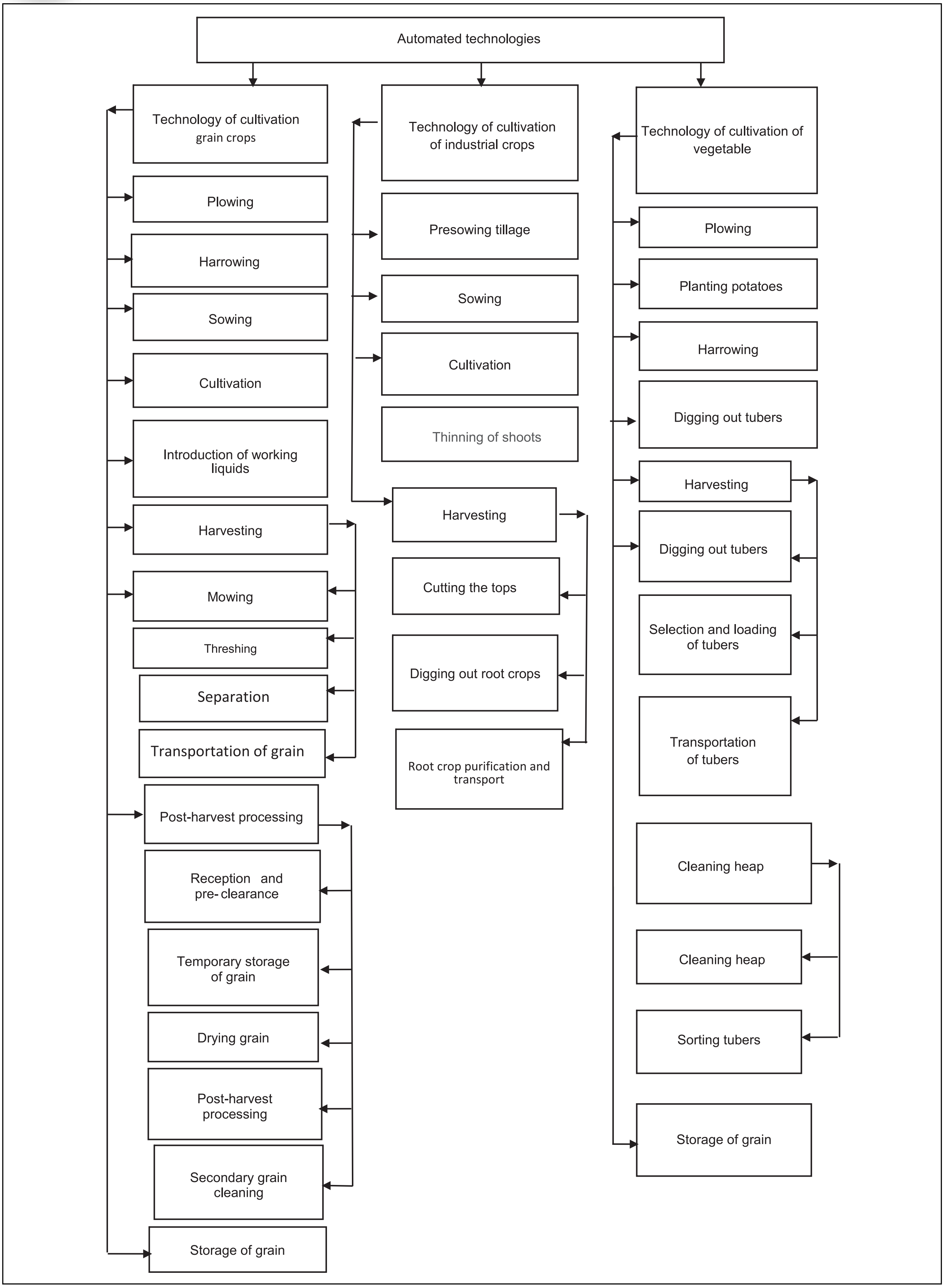

Fig. 1. Block diagram of automated technologies in plant growing

increases the efficiency of technological processes, through the line balance, optimal utilization of production capacity, rapid elimination of emergency situations with units, machines and individual processes that occur during the performance of technological operations.

Figure 1 presents a block diagram of automated technologies for the production of cereals, technical vegetable crops and potato.

At present, the requirements to the flexibility of production and to the promptness of making managerial decisions have sharply increased in the sphere of agricultural production, which in turn calls for the intellectualization and informatization of the management processes [3]. To this end, it is necessary to solve the following tasks:

- monitoring all technological processes of agricultural production;
- providing support for making managerial decisions based on mathematical modeling and the use of information and analytical systems;
- expert evaluation of decisions and their optimization.

Collection and analysis of incoming information about all technological processes of agricultural production in real time, identifying bottlenecks of production, emergency situations, unproductive outages of equipment and mobile facilities should be based on the use of digital technologies, mechatronics, the development of optimal algorithms for high-speed information flows and their mathematical support with taking into account the rapidly developing microprocessor means [4].

The system hardware and software of modern automated systems provide conditions for solving a wide variety of problems - organizational, technical, financial, psychological, including economic ones, and provide prompt and reliable information on the production status necessary for automatic generation of key indicators and adoption of optimal managerial decisions. The hardware and software produced by industry and foreign firms for automation systems include:

- programmable controllers;
- integrated management systems;
- distributed input-output stations;
- modular software;
- devices and systems of the man-machine interface;
- components of different communication;
- web-technologies;
- continuous process control systems;
- drive regulation and control systems;
- systems of so-called machine vision.

In this respect, the development of mathematical models and algorithmic support adequately reflecting such technological processes as soil cultivation, sowing, fertilizing, harvesting, post-harvest processing and storage of agricultural products is extremely important [5].

The application of a mathematical apparatus in solving the problem of optimizing the control system of agricultural production leads to finding the extremum of the target functional according to the given criterion of the entire enterprise efficiency.

The use of artificial intelligence in the control system allows to proceed to the controlling of the object (soil, plant, machine, technology) not by deviating one of the parameters or a group of parameters from the accepted norm, but in accordance with the function of the control object assignment and the constraints imposed by environmental requirements, the seasonal nature of work, and the impact characteristics of external factors [6, 7].

Together with the database (DB) obtained from a variety of sources of various systems, information is accumulated and consolidated in a single data storage, thus making an integrated information environment for solving a wide range of tasks, including the calculation of key indicators that are necessary for the analysis of production and technological situations.

Complex system analysis of production and technological situations in agricultural production includes:

- defining information requirements of users, that is, identifying the form, in which information should be provided to agronomists, livestock specialists, engineers, mechanics, and operators.
- determination of unknown factors influencing the production process;
- development of recommendations for the optimal management of production processors and the elimination of equipment downtime;
- visualization of the analysis results of economic activities of agricultural enterprises, preparation of reports on production and sales of products.

Integrated automated information management system for all technological processes in agricultural production should solve the following tasks:

- input of technological data during field works, in post-harvest processing and storage of agricultural products;
- transfer of technological data to the production and dispatch service, as well as their collection and storage in a centralized database;
- transfer of control commands from the higher levels of the common control system to the lower level;
- archiving data on all indicators in a general access format;
- generating reports and summaries.

Information coordination of technological and technical means ensures the maximum utilization of power and transport vehicles, as well as general purpose vehicles.

To solve such a problem, it is necessary to develop and create a database consisting of the following sections and subsystems:

1. *Regulatory reference and infrastructure subsystem* (an administrative unit implying the maintenance of regulatory information on):

- certification of fields in a digitized form;
- crops, including different varieties, stages of their development (life cycle) and optimal terms;
- crop rotation;
- types of fertilizers and plant protection products;
- types of soils;
- the infrastructure of a farm enterprise: departments, roads, permanent storage facilities, fuel depositaries, machine fleets, repair shops, rational paths connecting pairs of objects;
- types of tractors, vehicles, combine harvesters, forklifts, mounted implements, according to the maintenance regulations;
- field works and operations, as well as certification of fields in a digital form.

2. *Subsystem for collecting primary information about the control object* (system administrator, dispatcher) collecting and processing primary information:

- automatically taken from the sensors of mobile objects;
- taken from the control object manually;
- obtained by analysis of samples and equipment;
- urgent delivery of messages about unforeseen events to decision-makers (automatic delivery to dispatchers and company management).

3) *The subsystem of planning crop production works and the corresponding resource support* (planners-agronomists, mechanics, supply engineers) – planning:

- use of fields for farm produce growing;
- annual implementation of the plan for agricultural work for each field and all stages of the field campaign;
- the use of operations to carry out field works for each field and all stages of the field campaign;
- needs for machine resources for the performance of agricultural works with a breakdown by machine type and the timing of their involvement;
- need for fertilizers, plant protection means, fuels and lubricants, the timing of their purchase and transportation to storage facilities;
- evaluation of the required amounts of the utilization of internal machine resources, seeds, fertilizers, plant protection means, fuel for seeding, cultivation of crops, and harvesting;
- drawing up of the operative executive plan of the performance of works with a specification by fields and taking account of planned operations;
- formation of orders for the use of equipment and invoices for obtaining seeds, fertilizers, plant protection means, fuel and lubricants, and spare parts;
- adjustment of the executive plan for the performance of works (taking into account information on the state of soils, crops, the amounts of work performed) for the field in the conditions of the sowing campaign;
- a set of tasks for planning the transportation of crops.

4. *The subsystem of operational dispatch control of the performance of works and operations of crop production and the corresponding resource support* (dispatchers-agronomists):

- monitoring the quality of agricultural operations and their implementation;
- development of options for solutions (reactions) to unforeseen events (including the adjustment of the executive plan).

5) *Subsystem for assessing the state of control objects:*

- soil;
- crops in the field;
- the scope of work, including the field ones, as well as those on the restoration of resources;
- current resources (fertilizers, seeds, plant protection means, fuel and lubricants, equipment, free space of storage facilities, and personnel);
- losses incurred during the storage of agricultural products;
- technical base of stationary objects.

The principles of control and management of a multidimensional unified automated system include methods for assessing the status of the technological process as an object of control and management, deciding on the compliance of this management practice with the established requirements.

The implementation of these principles requires the elaboration of control and management algorithms. Such algorithms should be based on the dependencies connecting the statistics of the performance indicators of technological processes with tolerances and probabilities of their keeping or exceeding [8].

Agricultural units and their complexes operate under conditions of varying external influences [9].

The main types of them, in addition to climatic factors, include physical and mechanical properties of soil (moisture, density, granulometric composition); relief, road conditions, which determine the energy costs for unit movement and soil cultivation; properties of plants (yield, etc.), affecting the energy costs and quality of the machines; change in the unit mass and its technical state during the performance of a technological process.

The functioning of the unit is usually considered as a reaction to input disturbance and control actions. Figure 2 shows a generalized structural diagram of a tillage implement, which is one of the objects of the field subdivision.

The mathematical model of an object of automatic control of the tractor engine load on the scheme includes the transfer functions on the control channel – $W_{U1}(p)$, $W_{U2}(p)$, $W_{U3}(p)$, $W_{U4}(p)$, along the perturbation channel – $W_{f1}(p)$, along the cross links inside the object – $W_{П1}(p)$,

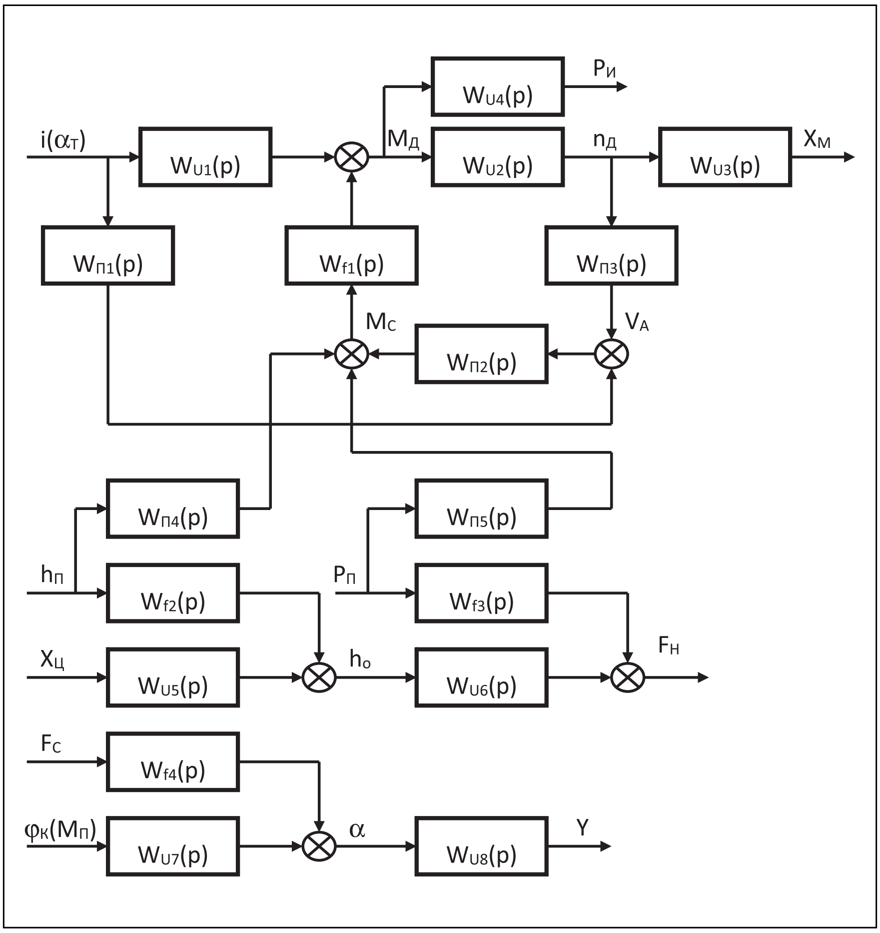

Fig. 2. Generalized structural scheme of ploughing MTA as a multidimensional object of automatic control

$W_{П2}$(p), $W_{П3}$(p), and between objects – $W_{П4}$(p) and $W_{П5}$(p).

The mathematical model of an object of automatic control of the soil tillage depth in the scheme includes the transfer functions along the control channel – W_{U5}(p), W_{U6}(p), along the perturbation channels – W_{f2}(p), W_{f3}(p), and cross links – $W_{П4}$(p), $W_{П5}$(p).

The mathematical model of an object of automatic driving of a machinery-and-tractor unit includes the transfer functions on the control channel – W_{U7}(p), W_{U8}(p) and the transfer function along the perturbation channel – W_{f4}(p), which are presented on the diagram.

The model of the unit functioning (control and automation of work) is represented in the form of a system, where the input is acted upon by the vector functions of the working conditions $X=[x_1(t), ..., x_n(t)]$, controls $U=[u_1(t), ..., u_m(t)]$ and the inner connections $\Phi=[\varphi_1(e), \ldots, \varphi_l(t)]$. This means that there are n perturbing, m control and l internal influences on the unit.

Output variables form a vector k-dimensional function $Y=[y_1(t), ...,y_k(t)]$, which determines the technological, energy, operational and other performance indicators for given vectors X, U and F.

The number of components n, m , l and k vectors depends on the unit type and the consideration degree of working conditions [10].

For the operational control of the efficiency of technological process, determined by the implementation of $y(t)$ at a specific period T, it is necessary to continuously have information about the implementation of $y(t)$, to find the statistics of this implementation and compare it with the tolerances basing on the given values of the tolerance Δy and the probability $P_{\Delta 3}$.

Such an algorithm for monitoring the efficiency of a technological process is hard to implement, because in the process of monitoring, it is necessary to form the average value of the $y(t)$ implementation, with which the current value of the control parameter should be compared.

It is more expedient to use as a deviation base the deviation of the implementation ordinates not the average implementation value $y(t)$, but the adjusting (nominal) value y_n. With a given a tolerance $\Delta_{ун}$ to the deviation of $y(t)$, the indices from the tuning value of y_n, and the generalized estimate of $P_{\Delta н}$ are implemented quite simply, because the ordinate values of the $y(t)$ implementation are directly compared with y_n. For a certain period of monitoring T in the measuring unit, due to the mathematical expected of my, estimates are formed:

$$P^{+}_{\Delta н} = T^{+}_{\Delta н}/T;\ P^{-}_{\Delta н} = T^{-}_{\Delta н}/T;\ P_{\Delta н} = P^{+}_{\Delta н} + P^{-}_{\Delta н}$$

$P_{\Delta n}$ – where the overall estimate of the probability of finding the implementation $y(t)$ in the tolerance field.

An algorithm for outputting information during soil cultivation and other technological operations for sowing, the introduction of liquid complex fertilizers and use of plant protection means, for the operation of a mobile agricultural unit has also been developed.

Figure 3 shows the algorithm for controlling the grain cleaning machine.

Results and discussion. The new generation of farming systems that are currently developed aims at ensuring the level of productivity of agrocenoses with a high coefficient of efficiency of the invested funds and the use of the landscape capacity, while the productivity of plants depends, first of all, on the availability in soil of mineral nutrients in the optimum ratio at each elementary section of the cultivated field, as well as on plant protection measures [10-14].

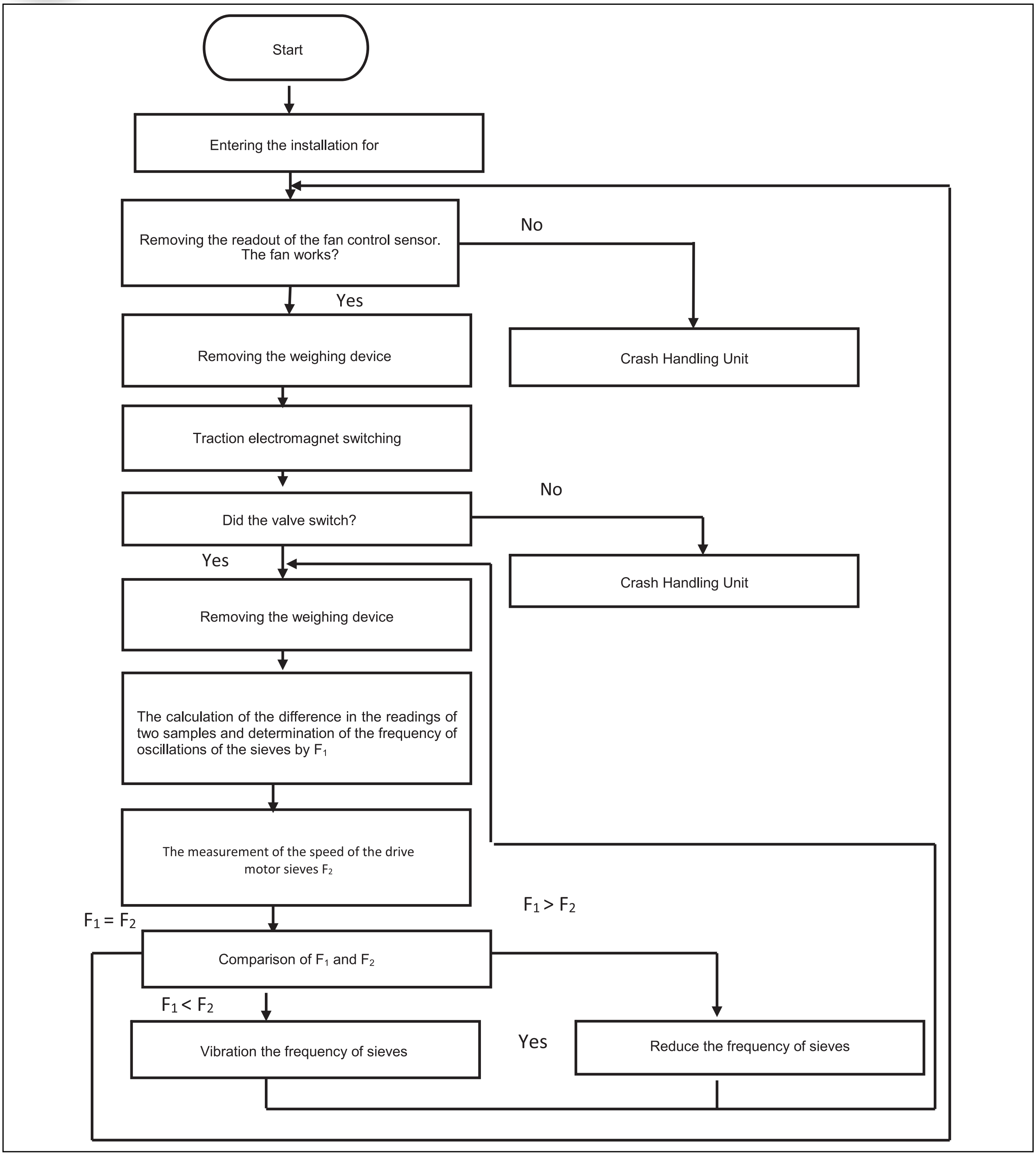

Fig. 3. Program algorithm for automatic control and regulation of a grain cleaning machine

Conclusions. Intensification of production and reduction of the farm produce cost cannot be introduced without the latest automated production information and control systems based on network technologies of data gathering, collecting, analyzing and developing optimal managerial solutions.

The emphasis on the quantitative analysis of the production situation allows to shift from logical-intuitive methods to a deeply formalized computer-assisted base in developing draft solutions.

REFERENCES

1. Izmaylov A.Yu., Lobachevskiy Ya.P. Sistema mashin i tekhnologiy dlya kompleksnoy mekhanizatsii i avtomatizatsii sel'skokhozyaystvennogo proiz-vodstva na period do 2020 goda [The system of machines and technologies for integrated mechanization and automation of agricultural production for the period up to 2020] // Sel'skokhozyaystvennyye mashiny i tekhnologii. 2013. N 6: 6-10. (In Russian)

2. Kargar AHB Automatic weed detection system and smart herbicide sprayer robot for corn fields. / Kargar AHB, Shrizadifar AM// RSI/ISM Int Conf on Robotics and Mechatronics; February. pp: 13-15. 2013.

3. Izmaylov A.Yu., Khoroshenkov V.K., Kolesnikova V.A., Alekseyev I.S., Lonin S.E., Goncharov N.T. Sredstva avtomatizatsii dlya upravleniya sel'skokhozyaystvennoy tekhniki [Means of automation for controlling agricultural machinery] // Sel'skokhozyaystvennyye mashiny i tekhnologii. 2017. N3: 3-9. (In Russian)

4. Jensen K. A low cost, modular robotics tool carrier for precision agriculture research./ Jensen K., Nielsen S.H., Jorgensen R.N., Bogild A., Jacobsen N.J., Jorgensen O.J., Hansen C.L.J. // Proc Int Conf on Precision Agriculture; July – 2012.

5. Krishnaswamy R. Aravind, Purushothaman Raja and Manuel Pérez-Ruiz Task-based agricultural mobile robots in arable farming: A review / Spanish journal of agricultural research, 15(1) March 2017. 3-16.

6. Grimstad L. Initial field-testing of Thorvald, a versatile robotic platform for agricultural applications./ Grimstad L., Phan HNT, Pham C.D., Bjugstad N., From P.J. // Proc of the IROS Workshop on Agri-Food Robotics. October 2015. 23-29.

7. Ustoychivaya optimizatsiya sel'skokhozyaystvennogo proizvodstva [Sustainable optimization of agricultural production] Basil Manos, Parthena Chatzinikolaou, Fedra Kiomourtzi ICESD 2013: January 19-20, Dubai, UAE.

8. Izmaylov A.Yu., Khoroshenkov V.K. Avtomatizirovannaya sistema upravleniya posevom i vneseniyem udobreniy // Sel'skokhozyaystvennyye mashiny i tekhnologii. 2011. N4: 9-12. (In Russian)

9. Yelizarov V.P., Antyshev N.M., Beylis V.M. Shevtsov V.G. Iskhodnyye trebovaniya na tekhnologicheskiye operatsii v rasteniyevodstve [Initial requirements for technological operations in plant cultivation] // Sel'skokhozyaystvennyye mashiny i tekhnologii. 2011. N1: 11-14. (In Russian)

10. Khoroshenkov V.K., Goncharov N.T., Luzhnova Ye.S., Mal'tsev N.V. Avtomatizatsiya upravleniya mashinno-traktornym agregatom s ispol'zovaniyem navigatsionnykh sistem [Automation of the control of a machine-tractor unit with the use of navigation systems] // Tekhnika v sel'skom khozyaystve. 2010. N3: 19-23. (In Russian)

The paper was submitted to the Editorial Office on 03.04.2018 The paper was accepted for publication on 27.04.2018

Conflict of interest. The authors declare no conflict of interest.

DOI 10.22314/2073-7599-2018-12-3-12-16

Determination of the Bonding Force Between the Rettery and Flax Swaths in Their Picking Up by Pick-Up Device Fingers

Viktor G. Chernikov, Dr.Sci.(Eng), Professor, Corresponding Member of the Russian Academy of Sciences, Chief Researcher;

Vladislav Yu. Romanenko, Ph.D.(Eng), Head of Laboratory

All-Russian Research Institute for Flax Production (VNIIML), Komsomolsky Ave., 17/56 Tver, 170041, Russian Federation, e-mail: v.romanenko@vniiml.ru

Abstract. The quality of flax products depends on the way of flax straw retting. Currently, the best and most widely used method of flax straw retting is way of dew retting. Flax stems are laid in a thin layer on the flax field where they were grown or on a clover or grass field. During the retting process, plants tend to grow through the flax swaths depending on the air temperature (starting from 18°C) and humidity (50-60%). Therefore, the flax straw picking up process should be done with certain efforts, however, without damaging the stems. (*Research purpose*) To determine the bonding forces of the flax straw with the rettery (a flax field or a grass field). (*Materials and methods*) The authors have designed an instrument to measure and register the considered forces as well as a general mechanism of the flax straw picking up process, which operates in conjunction with the IP 264 (BS) measurement information system, and also developed a research methodology. This system is integrated with to a laptop with the pre-installed «Testing» software. The system is adopted to use the MS Excel software to transfer data in MS Excel format for further plotting. (*Results and discussion*) It has been shown that the bonding forces of flax stems, their changing pattern, and the maximum value during the picking up process depend on the degree of penetration by grass plants into flax swaths and the grass plant density per square meter. (*Conclusions*) In process of picking up the grass-penetrated swaths, they show weak strength characteristics for transportation and an increased tendency to break the continuity of their picking up. The values of the ratio of the translational speed of a pick-up device and the rotary speed of a picking device fingertip can be greater than the value of the relative elongation at the point of pulling the swath away from the ground. The coefficient of strength to pick up the swaths from a clover rettery is higher than that of flax and grass retteries.

Keywords: retted flax straw, flax field, flax stems, bonding force, coefficient of strength.

For citation: Chernikov V.G. , Romanenko V.Yu. Determination of the bonding force between the rettery and flax swaths in their picking up by pick-up device fingers. *Sel'skokhozyaystvennye mashiny i technologii*. 2018. 12:(3): 10-13. DOI 10.22314/2073-7599-2018-12-3-12-16. (In Russian)

Flax harvesting includes a number of successive operations: stalking of stems, detaching seed boxes, laying stems down for retting, their picking up, and the transportation of packs. A special place among the operations listed above belongs to the picking up of stems and pressing them into large packs, which largely determines the quality of products [1]. The production of long fiber on flax factories largely depends on the quality of a retted flax straw and its condition after its picking up. In other words, it depends on the right selection of the method of its obtaining.

The most widespread method is dew retting. At present, it is considered the best one [2]. The stems of flax are laid in a thin layer in a rettery on a field from under clover or flax (where it was previously grown). During the retting process, the swath is penetrated by growing grass at a temperature of 18°C and an air humidity of 50-60%. Therefore, for picking it up, it is necessary to exert a certain effort not to damage the stems.

Choosing a rotary speed of the tips of the -up fingers, as well as the interaction mechanism of the pick-up device's moving fingers with the picked up swath can be considered only on the basis of sufficient data on the stiffness of the retted flax stems and their connection with the rettery.

To ensure the cleanliness of the swath picking up from the rettery and the obtaining of long fiber without losses, it is necessary that the swath enter the pick-up device without tearing and piling up, and this depends on the setting of rotary speed of the picking device fingertips, and the value of the interaction force between the fingers and the stems [1-4].

Purpose of research – is to determine the value of the binding forces between retted flax stems and the rettery and the cohesion coefficient of the stems.

Materials and methods. To record and measure the analyzed forces, as well as to identify separate phases of the picking up process, a device was developed that functions in conjunction with the IP 264 (BS) measurement information system (Fig. 1). The system is designed for research purposes, as well as power, operational and technological evaluations of machines and traction testing of tractors. It receives discrete and analog signals from primary converters of any type. The instrument and the schematic diagram of the measurements are shown in Figure 2.

The figure shows power link *1* and devices located in the mobile IP 264 (BS) measuring system. This system was connected to a mobile computer, with the embedded «Testing» software that can transfer data in MS Excel format for further plotting purposes.

Fig. 1. General view of the testing system IP-264 connected to the laptop and the module of coordination MC-1

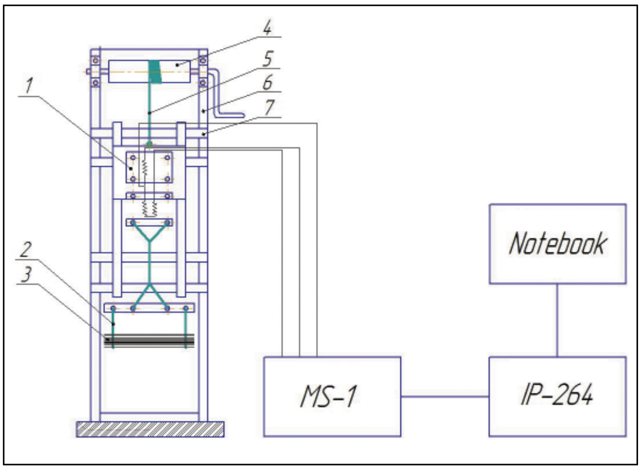

Fig. 2. The device and the basic scheme for the measuring of bonding forces of the flax stems swaths with the field

The power link is an elastic rubber plate of rectangular cross-section 30×40 mm with two wire sensors attached to it.

The connection between the power link, the PI 264 (BS) measuring system and the laptop is carried out using a wired connection. A portable 12 V power supply was used for tests.

Results and discussion. Experiments were carried out in the Bezhetsk district of the Tver region. The device was installed along the laid swath. The ends of flexible cables *2* passed under swath *3* so that the connection between the retted flax stems and the rettery could not be not broken. When drum *4* was rotating, cable *5* was wound on it, moving upwards along rails *6* of slide *7*. The slide entrained a rubber plate with sensors attached to it (a power link), which was connected to the picked up retted flax stems through the wire and rail.

Due to the binding forces between the retted flax stems and the rettery, the rubber plate was deformed, and the working sensors attached to its surfaces deformed as well.

When the sensors were deformed, their resistance changed, and, consequently, the bridge left the balance state: the current entered the matching module MS-1, from it to the IP 264 (BS) system, and then the signal entered the laptop, which registered the efforts of the stems' connection with the rettery.

Each of the experiments had a tenfold retake on different swaths and with a different number of simultaneously picked up stems.

Previously, the power link was calibrated by deforming it in conditions similar to the operating ones. Figure 3 shows the load characteristic of the power link.

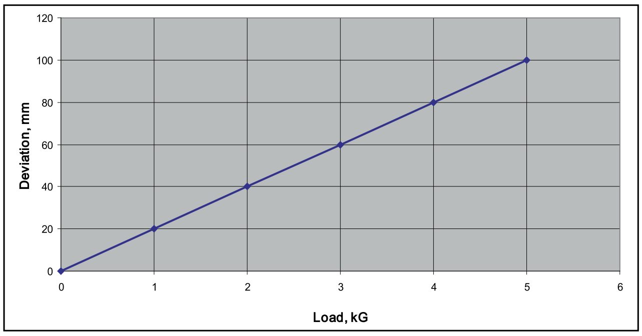

Fig. 3. Load characteristic of the power link

Oscillograms recorded the nature of changes in the binding forces of the flax stems during their ascent, and the value of the maximum bond strength for a certain number of stems.

If we compare the nature of changes in the curves on the oscillograms of different experiments (with a different number of stems), it will be easy to see that, regardless of the number of stems, the curves on the oscillograms are similar in shape and differ only in the magnitude of the ordinates. We can distinguish three characteristic areas on each oscillogram (Fig. 4).

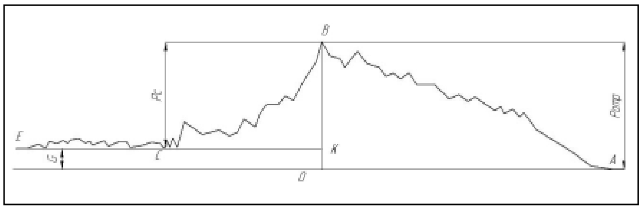

Fig. 4. Characteristics of the phases of a flax swath's detachment: A –beginning; B – maximum banding force; C – the ending of detachment

Section *AB* – the section corresponds to the maximum tearing resistance of the stems. Point A – the beginning of the phase of separation of flax stems from the rettery (breaking of the bonds of the captured stems with the grass cover of the rettery and the stems of neighboring swaths). Point B is the maximum binding force of flax stems with the rettery that corresponds to the moment of tearing the stems away from the rettery for most of them along the swath width.

The second section BC – there is further and final tearing away of the stems along the entire swath width with a characteristic drop in the binding force. The point C corresponds to the end of the phase of tearing the flax stems from the rettery.

Section CE is parallel to the axis of abscissas and corresponds to the mass of picked up flax stems from the rettery. Point E is the end of the detachment of the flax stems from the rettery.

As noted above, point B corresponds to the maximum value of the binding force between the flax stems and the rettery, and its value on the oscillograph – to the ordinate BO. We denote it as $P_{отр}$. The ordinate KO on the oscillogram corresponds to the mass of the picked up stems G. So the difference between $P_{отр}$ and the mass of the stems is regarded as the binding force between the stems and the rettery, that is $P_{сц}$, which corresponds to the ordinate BK on the oscillogram. Mathematically, this relationship can be expressed by the formula:

$$P_{сц} = P_{отр} - G, \tag{1}$$

or

$$P_{отр} = P_{сц} + G. \tag{2}$$

The binding force $P_{сц}$ between the stems and the rettery can be expressed as:

$$P_{сц} = l_{ср}\, c f_{сц}, \tag{3}$$

where $l_{ср}$ – the average length of stems, m;

c – the length of the stem gripping area, m;

$f_{сц}$ – the coefficient of adhesion or tearaway resistance of stems, kG/m^2 [5, 6].

The product $l_{ср}c$ is the area occupied by the picked up stems, m^2. If the average number of stems "n" is known, *pcs./run. m*, it is easy to establish the relationship between the number of stems, *m/pcs*, located on the interval c and n [7]:

$$m = cn, \tag{4}$$

or

$$c = m/n. \tag{5}$$

Formula (3) can be represented as:

$$P_{сц} = l_{ср}\frac{m}{n} f_{сц}, \tag{6}$$

If we insert the value of the binding force $P_{сц}$ in formula (2), we obtain:

Table

Change in the detachment force $P_{отр}$ depending on the number of picked up flax stems and the type of rettery

Number stems, pieces	Bonding force $P_{отр}$, kg		
	Flax field with the plants of biomass in 105 g/m^2	Flax field with the plants of biomass in 137 g/m^2	Flax field with the plants of biomass in 150 g/m^2
50-100	1,4	1,7	1,9
100-150	1,6	2,1	2,1
150-200	1,9	2,3	2,4
200-250	2,1	2,8	2,9
250-300	2,3	3,0	3,0
300-350	2,6	3,2	3,3
350-400	2,8	3,4	3,6
400-450	3,0	3,6	3,7

$$P_{отр} = l_{ср}\frac{m}{n} f_{сц} + G, \tag{7}$$

The weight of the picked up stems from the interval C can be expressed by the formula:

$$G = q_{ср}\, m, \tag{8}$$

where $q_{ср}$ – the average weight of a single stem.

Thus, equation (7) can be represented as follows (8):

$$P_{отр} = l_{ср}\frac{m}{n} f_{сц} + q_{ср} m, \tag{9}$$

As experimental studies have shown, for different rettery types, this force varies significantly with the same number of stems and depends on the grass height, its density and type, as well as some other factors.

The average value of the detachment force, depending on the number of stems, as well as the limits of its vibration, depending on the type of rettery with the same number of stems m, are given in the table.

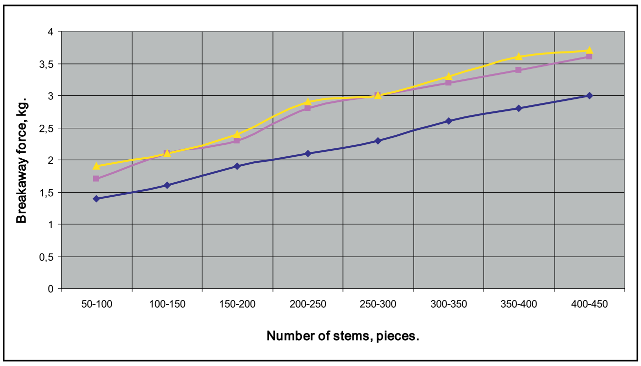

Fig. 5. Dependence of the bonding force P on the number of lifted stems: yellow line – flax field with the plants of biomass in 150 g/m^2; pink line – Flax field with the plants of biomass in 137 g/m^2; blue line – Flax field with the plants of biomass in 105 g/m^2

The dependence of the detachment force $P_{отр}$ on the number of stems is shown in Figure 5. The experimentally determined values of $P_{отр}$ for different types of rettery, with reference to formula (9), make it possible to calculate the limits of changes in the tearaway resistance coefficient of the flax stems, for swaths laid:

- in a flax rettery = 0.0015 – 0.0020 kg/cm^2;
- in a grass rettery = 0.001 – 0.0018 kg/cm^2;
- in a clover rettery = 0.0025 – 0.0046 kg/cm^2.

Conclusion

Improving the quality of raw flax resources, which determines the competitiveness of the industry, requires studying the features of flax harvesting under various conditions of retted flax maturing and applying technical means that most effectively perform technological steps [8]. The experiments carried out to study the peculiarities of detaching flax swaths prepared on different backgrounds have established that:

- the larger the grass height and density is, or the more the grass has penetrated the swath, the higher the tearaway resistance coefficient is, and therefore the greater the effort it takes to tear away the stems from the ground is;
- the coefficient of tearaway resistance of a swath laid on a clover rettery is greater than that for flax and grass retteries;
- when an interpenetrated swath is picked up, the values of the ratio of the translational speed of a pick-up device and the rotary speed of a picking device fingertip can be greater than the value of the relative elongation at the point of pulling the swath away from the ground.

REFERENCES

1. Chernikov V.G., Rostovtsev R.A., Romanenko V.Yu. Issledovanie podbirayushchego apparata s zhestkimi zubyami [Study of the pick-up mechanism with rigid teeth] // *Selskokhozyaystvennye mashiny i tekhnologii*. 2011. N2: 34-36. (In Russian)

2. Rodionova A.Ye. Tekhnologiya vyrashchivaniya i pervichnoy pererabotke lna-dolguntsa [Technology of cultivation and primary processing of fiber flax] // Monograph. Tver. 2008: 442. (In Russian)

3. Chernikov V.G., Rostovtsev R.A., Romanenko V.Yu., Puchkov Ye.M Vliyanie kharakteristik usloviy raboty na nadezhnost i tochnost vypolneniya tekhnologicheskikh protsessov lnouborochnymi mashinami [Influence of working conditions on the reliability and accuracy of technological processes performed by flax harvesting machines] // *Mekhanizatsiya i elektrifikatsiya selskogo khozyaystva*. 2016. N4: 9-11. (In Russian)

4. Rostovtsev R.A., Dmitriev V.I. Opredelenie koeffitsienta treniya stebley o poverkhnost pochvy [Determination of the coefficient of friction between stems and the soil surface] // *Dostizheniya nauki i tekhniki APK*. 2006. N4: 16-18. (In Russian)

5. Kovalev M.M., Apykhin A.M., Lachuga D.Yu., Tolstushko N.A. Povyshenie effektivnosti pressovaniya lnovolokna v kipy [Increasing the efficiency of pressing flax fiber into bales] // *Silskogospodarski mashiny*. 2014. N27: 61-67. (In Russian)

6. Shilo I.N., Dashkov V.N. Resursosberegayushchie tekhnologii selskokhozyaystvennogo proizvodstva [Resource-saving technologies of agricultural production] // Monograph. Minsk. 2003: 182. (In Russian)

7. Uschapovsky I. The Russian flax sector: bottlenecks and solutions // *Journal of Natural Fibers*. 2009. 6. N1: 108-113. (In English)

8. Marchenkov A., Rozhmina T., Uschapovsky I., Muir A.D. Cultivation of flax // Flax: the genus Linum. Edited by Alister D. Muir and Neil D. Westcott. New York, 2003: 74-91. (In English)

The paper was submitted to the Editorial Office on 19.04.2018 The paper was accepted for publication on 22.05.2018

Conflict of interest. The authors declare no conflict of interest.

CC BY

DOI 10.22314/2073-7599-2018-12-3-17-21

Efficiency Evaluation of Grain Harvesters of Different Types under North Kazakhstan Conditions

Vladimir L. Astafyev[1],
Dr.Sc. (Eng), Professor, Director;

Eduard V. Zhalnin[2],
Dr.Sc. (Eng), Professor, Key Research Engineer

[1]Kostanay Branch of LLP "Kazakh Scientific Research Institute of Farm Mechanization and Electrification", Kostanay, Kazakhstan, e-mail: vladast01@mail.ru;
[2]Federal Scientific Agroengineering Center VIM, Moscow, Russian Federation, e-mail: vim@vim.ru

Abstract. The problem of selecting certain types of grain combine harvesters is quite urgent now. This is because the agricultural manufacturers are struggling to make a right selection of a grain harvester of a definite firm or make due to the aggressive marketing from the manufacturers. (*Research purpose*) Efficiency evaluation of grain harvesters of different types under the North Kazakhstan weather conditions. (*Materials and methods*) Technical and economic research has been performed according to the standard methodology followed by data analysis. The calculation has been made for direct combining by 4, 5 and 6-class harvesters equipped with wide-cut headers from leading domestic and foreign manufacturers. (*Results and discussions*) the authors have also calculated direct costs for thrashing of one ton of grain under favorable harvesting conditions, total costs for thrashing of one ton of grain including grain losses under unfavorable harvesting conditions, as well as total costs for thrashing of one ton of grain considering that 30 percent of grain is harvested under favorable harvesting conditions and 70 percent – under the ones. (*Conclusion*) It has been found that the price of thrashing of one ton of grain that characterizes the efficiency of utilizing grain harvesters depends on the price/efficiency ratio of a harvester, yield and harvesting conditions. Combine harvesters of a lower class with the optimum price/efficiency ratio are more preferable under favorable harvesting conditions. However, in case of the harvest period prolongation due to unfavorable harvesting conditions, combine harvesters of a higher class are more preferable.
Keywords: grain combine harvesters, efficiency, weather conditions, price of one ton of thrashed grain.

For citation: Astafyev V.L., Zhalnin E.V. Efficiency evaluation of grain harvesters of different types under North Kazakhstan conditions. *Sel'skokhozyaystvennye mashiny i tekhnologii*. 2018. 12(3): 14-17. DOI 10.22314/2073-7599-2018-12-3-17-21. (In Russian)

In Northern Kazakhstan, there are farms of different categories (personal farms, medium-size and large agricultural enterprises) with arable land areas of 300-3000 *ha*, 3000-10000 *ha*; and more than 10000 hectares, respectively. Moreover, large and medium-size farms, in which 71% of the regional arable land acreage is concentrated, account for more than 20%, [1]. The beginning of the harvest period (the third decade of August) is usually dry, but in September, as a rule, it begins to rain. The yield capacity in the region amounts to about 13 hwt per hectare with fluctuations from 8 hwt per hectare in dry years to 19 hwt per hectare in the wet ones.

In recent years, grain harvesters of various capacities from different countries have been delivered to operate in the region. There is an increase in the share of medium and high-class harvesters from "near and far abroad". This is due to the limited periods of favorable weather in the autumn period in the region and the desire of agricultural producers to maximize the productivity of machines in the harvesting process under a shortage of machine operators. The solution to the problem of choosing and effective operating a certain harvesting machine encounters. This is due to the fact that under conditions of aggressive advertising of the equipment to be sold by its manufacturers, it is not easy for agricultural producers to make the right choice in favor of a certain firm, or abrand of a combine harvester [2-5].

Research of purpose is to evaluate the effectiveness of the application of combine harvesters of various classes in the conditions of Northern Kazakhstan, taking into account weather conditions.

Materials and methods. Technical and economic studies have been carried out in accordance with a standard procedure followed by an analysis of the results obtained. The calculation has been performed for a technological operation of direct combining by different brands of combine harvesters (Tab. 1).

In the Republic of Kazakhstan, grain harvesters are aggregated with headers and reaper-headers of different widths.

The calculation is based on the maximum cutting width of header and reaper-header. Wide headers provide for the most complete loading of combines basing on their throughput capacity.

The travel speed of combines for a given yield has

Table 1

Characteristics of grain combine harvesters

Characteristics	Esil-740*	Medion-310	Acros-530	Mega-360	9660-STS
Manufacturer country	Kazakhstan	Germany	Russia	Germany	USA
Harvester class	4	4	5	5	6
Throughput capacity, kg/s	7.7	7.9	10.0	10.4	13.0
Width of header, m	7.0	7.0	9.1	9.0	11.7

*Esil-740 is a counterpart model of the Belorussian 4-class КЗС-740 "Polesiye" combine harvester

been calculated using the formula given below taking into account the zonation coefficient [6]:

$$V_p = \frac{q \cdot K_з \cdot 10}{B \cdot \beta \cdot У \cdot (1+\delta)}, \quad (1)$$

where $V_р$ is the working speed, *m/s*;

q – throughput capacity, *kg/s*;

$K_з$ – coefficient of zonal conditions;

B – header width, *m*;

β – coefficient of the header width use;

$У$ – crop yield, *t/ha*;

δ – straw ratio.

It has been taken into account that, with a yield of up to 20 *hwt/ha*, the 4-class harvesters have operating speed limits of 2.20 *m/s*; class 5 – 2.50 *m/s* and 6-class combine harvesters – 3.06 *m/s*. When the given speeds exceed the expected yields, grain losses increase sharply. Taking into account the speed of the combine and the header width, we have calculated the productivity for 1 hour of the shift time:

$$W_{см} = 0{,}36 \cdot B \cdot \beta \cdot V_р \cdot K_{см} \quad (2)$$

where $W_{см}$ – shift productivity, *ha/h*;

$K_{см}$ – the coefficient of time shift use.

Total costs for harvesting grain by comparable combine harvesters have been calculated by the formula:

$$C_к = \frac{C_э}{W_{см}} + П_у, \quad (3)$$

where $C_к$ – composite costs, *$/h;*

$C_э$ – operating (direct) costs, *$/h*;

$П_у$ – cost of losses, *$/h.*

The difference in the composite costs for the compared harvesters is considered significant if it exceeds the expected value by 5%.

Operating costs have been calculated as follows:

$$C_э = C_а + C_р + C_о + C_т, \quad (4)$$

where $C_а$ – depreciation costs, *$/h*;

$C_р$ – repair costs, *$/h*;

$C_о$ – labor costs, *$/h*;

$C_т$ – cost of fuel, *$/h.*

If we assume that the most productive (reference) harvester can harvest without losses, the number of working days that are accompanied by losses can be calculated for less productive combines by the formula:

$$Д = Д_{опт} \cdot \left(\frac{W_б}{W_р} - 1\right), \quad (5)$$

where $Д$ – the number of days accompanied by losses, days;

$Д_{опт}$ – number of optimal days for harvesting, days;

$W_б$ – performance rate of a reference combine, *ha/h* (*t/h*);

$W_р$ – the productivity of the compared combine, *ha/h* (*t/h*).

The grain loss resulting from incomplete harvest has been determined by the formula:

$$П_у = K_п \cdot C_п \cdot Д \cdot У, \quad (6)$$

where $П_у$ – losses from incomplete harvest, *$/ha*;

$K_п$ – the daily intensity of crop losses when prolonging the working period as compared to the optima one, share/day; $K_п = 0.01$ *t/ha*;

$C_п$ – purchase price, *$ 120/ton*.

$У$ – productivity, *t/ha*;

If we divide the right-hand side of the expression (6) by the yield, we get the amount of loss, $ per ton.

Results and discussion. The calculation results of the cost of harvesting 1 ton of grain by combine harvesters under favorable conditions without prolonging the working period are presented in Table 2.

Table 2

Cost of one ton of grain harvested by the compared harvesters under favorable conditions

Harvester	Direct costs per 1 ton, $ at a given yield, centner/ha		
	10	15	20
Esil-740	19.27	16.56	16.16
Medion-310	25.46	19.80	18.89
Acros-530	23.73	18.57	18.09
Mega-360	28.50	21.88	20.54
9660-STS	24.13	21.73	20.74

Combines can be ranked as to the cost of harvesting 1 ton of grain. The lowest price of grain threshing in favorable weather conditions is provided by the class 4 combine Esil-740, which is explained by the best ratio between its price and productivity. The second place in terms of increasing the cost of 1 ton of grain is confidently taken by the Akros-530 harvester. The cost of 1 ton of grain harvester by combine harvesters 9660-STS, Mega-360 and Medion-310 at a yield of 10-15 *hwt/ha* is by 3-5 *$/t* more, and at a yield of 20 *hwt/ha* by $ 5-9 per ton more than the cost of grain threshing with combine Esil-740.

The offered ranking is valid for favorable weather conditions and the absence of biological losses due to untimely performance of operations. In case of down time due to precipitation, the most significant biological losses have been detected for a combine with lower productivity. This is due to the fact that such a combine has the largest area to be harvested for the period of precipitation, which results in such losses. Taking into account losses from untimely performance of operations, the total costs per 1 ton of grain will be as follows (Tab. 3).

Table 3

Total costs of thrashing one ton of grain by compared harvesters under unfavorable weather conditions during harvesting period

Harvester	Composite costs per 1 ton, $ at a given yield, centner/ha		
	10	15	20
Esil-740	34.73	27.75	26.70
Medion-310	40.69	31.27	28.14
Acros-530	29.72	22.04	20.11
Mega-360	35.03	25.83	22.37
9660-STS	24.13	21.73	20.74

Under unfavorable conditions and the fact of losses due to untimely performance of operations, the more efficient combine harvesters 9660-STS, Akros-530, then Mega-360, then Esil-740 and Medion-310 should be given priority.

In conditions of Northern Kazakhstan, less than 50% of the area is harvested under favorable weather. The research has been carried out in the southern districts of the region with an average yield level of about 10 hwt per hectare. Under the precipitation are areas with an average yield level of about 20 *hwt/ha*. Taking account of this fact, let us assume that under the conditions of the northern part of Kazakhstan, 30% of the grain is harvested under favorable weather and 70%, under unfavorable. Calculation results of the cost of threshing 1 ton of grain by comparable harvesters under these conditions is shown in Table 4.

Table 4

Composite costs depending on compared combine harvesters with volume-to-volume ratio of grain harvested during favorable weather conditions and pre-cipitations, about 30:70

Harvester	Composite costs per 1 ton, $ at a given yield, centner/ha		
	10	15	20
Esil-740	30.09	24.39	23.54
Medion-310	36.12	27.83	25.37
Acros-530	27.92	21.00	19.50
Mega-360	33.07	24.65	21.82
9660-STS	24.13	21.73	20.74

At a ratio of the amounts of grain threshed under favorable weather and precipitation 30:70, the ranking of harvesters by the cost of threshing proceeds as follows: at a yield of 15-20 hwt per hectare, the lowest cost of grain threshing is provided by the 5 class combine Akros-530, by *$1/t* more grain as compared to combine harvester 9660-STS.

At a yield of 10 *hwt/ha*, the lowest cost of grain harvesting is ensured by the 6 class 9660-STS combine harvester by *$ 4/t* more than the cost of grain from the 5 class Akros-530 combine harvester. Combine harvesters Yesil-740 and Mega-360 provide the higher cost of threshing than the Akros-530 and 9660-STS at 2-3 *$/t* at a yield of 15-20 *c/ha*, and 3-9 *$/t* at a yield of 10 *hwt/ha*. Medion-310 gives the highest cost of threshing at a ratio of the amount of grain harvested under favorable weather and precipitation as 30:70.

Thus, under favorable harvesting conditions, priority should be given to combine harvesters of a lower class with an optimal price-quality ratio. However, if there is a danger of prolonging the harvesting period due to unfavorable weather conditions, priority should be given to higher-class harvesters. The results complement SIBIME studies, which show that in Siberia's extreme conditions, direct costs of harvesting by higher-class harvesters may be less than those for lower-class harvesters [7]. However, according to SIBIME, the lower threshold of the effective use of high-performance combines of leading foreign companies corresponds to yields of 35-40 *c/ha*. According to our research, under unfavorable harvesting conditions, this threshold can be significantly lower if these harvesters are equipped with wide-cut headers. The results of our studies confirm the conclusions of V.D. Saklakov that «for every technical means (machine-tractor unit) there is an optimal duration of field operations» [8-11].

Conclusions:

1. The cost of harvesting 1 ton of grain, characterizing the efficiency of the use of combine harvesters, depends on the ratio between the price and performance of the combine, yield, and harvesting conditions.

2. Under favorable conditions in the absence of losses from untimely performance of harvesting operations, the use of 4 and 5-class Esil-740 and Akros-530 combine harvesters is most effective, the higher costs are determined for the Medion-310, 9660-STS and Mega-360 combine harvesters.

3. Under unfavorable harvesting conditions, priority as to the effectiveness of use should be given in descending order to 6 and 5-class 9660-STS and Akros-530combine harvesters, followed by Mega-360, and also 4-class Esil-740 and Medion-310 combine harvesters.

4. In actual circumstances, periods with favorable and unfavorable weather conditions are both fairly probable during harvesting operations. In this respect, the combine harvester fleet of Northern Kazakhstan should be made up of mainly 5 and 6-class combine harvesters equipped with wide-cut headers and reaper-headers.

REFERENCES

1. Astaf'yev V.L., Gayfullin G.Z., Gridin N.F. et al. Rekomendatsii po tekhnicheskomu obespecheniyu vnedreniya vlago-resursosberegayushchikh tekh-nologiy vozdelyvaniya zernovykh kul'tur [Recommendations on technical support for the implementation of moisture-resource-saving technologies for the cultivation of grain crops]. Kostanay, 2008. 44.

2. Golikov V.A., Astaf'yev V.L., Selikhov V.T. Rezul'taty ispytaniy importnykh zernouborochnykh kombaynov v Severnom Kazakhstane [Results of tests of imported grain harvesters in Northern Kazakhstan] // *Traktory i sel'skokhozyaystvennyye mashiny*. 2000. N8. 42-43. (In Russian)

3. Zhalnin E.V. Kakiye kombayny nuzhny rossiyskomu polyu [What types of combines are needed for the Russian field] // *Sel'skiy mekhanizator.* 2006. N5. 6-7. (In Russian)

4. Zhalnin E.V. Effektivnoye ispol'zovaniye zernouborochnykh kombainov [Effective use of combine harvesters] // *Sel'skiy mekhanizator*. 2013. N9. 5-7. (In Russian).

5. Astaf'yev V.L., Malygin S.L. Effektivnost' zernouborochnykh kombainov razlichnykh klassov v usloviyakh Kazakhstana [Efficiency of using combine harvesters of various classes in Kazakhstan conditions] // *Vestnik sel'skokhozyaystvennoy nauki Kazakhstana*. 2011. N5. 86-91. (In Russian).

6. Metodika opredeleniya ekonomicheskoy effektivnosti tekhnologiy i sel'skokhozyaystvennoy tekhniki, chast' II. Normativno-spravochnyy material [Methods for determining the economic efficiency of technology and agricultural machinery, Part II. Normative reference material]. M.: 1998. 251. (In Russian).

7. Zhalnin E.V. Rezervy povysheniya effektivnosti proizvodstva [Reserves of increasing the production efficiency] // *Sel'skiy mekhanizator*. 2012. N1. 12-13. (In Russian).

8. Chepurin G.Ye., Ivanov N.M., Kuznetsov A.V. i dr. Uborka i posleuborochnaya obrabotka zernovykh kul'tur v ekstremal'nykh usloviyakh Sibiri: Rekomendatsii [Harvesting and after-harvesting processing of cereals in extreme conditions of Siberia. Recommendations]. M: Rosinformagrotekh. 2011. 176. (In Russian).

9. Saklakov V.D. Teoreticheskiye osnovy optimizatsii tekhnicheskoy osnashchennosti i trudoobespechennosti proizvodstvennykh protsessov v ras-teniyevodstve [Theoretical bases of optimization of technical equipment and labor availability of production processes in crop growing] // *Vestnik ChGAU*. 1996. 15: 83-97. (In Russian).

10. Kormanovskiy L.P., Krasnoshchekov N.V., Chernoivanov V.I., Nasypayko I.G., Sazonov S.N. Kontseptsiya razvitiya inzhenerno-tekhnicheskogo servisa fermerskikh khozyaystv [The concept of development of engineering and technical service in farms]. – Moscow: Vserossiyskiy nauchno-issledovatel'skiy tekhnologicheskiy institut remonta i ekspluatatsii mashinno-traktornogo parka Rossel'khozakademii, 1992. 49.

11. Masek J., Novak P., Pavlicek T. Evaluation of combine harvester fuel consumption and operation costs // 14th International Scientific Conference Engineering for Rural Development Proceedings, 14. Jelgava, 2015. 78-83.

The paper was submitted to the Editorial Office on 15.05.2018 The paper was accepted for publication on 07.06.2018

Conflict of interest. The authors declare no conflict of interest.

CC BY

DOI 10.22314/2073-7599-2018-12-3-22-27

Decomposition of Technological Processes for Evaluating the Performance of Production Line for PreSowing Treatment of Seeds

Ermat I. Kubeyev,
Dr.Sc. (Eng), Professor of Department,
kubeevei@ystu.ru;

Boris S. Antropov,
Dr.Sc. (Eng), Professor of Department

Yaroslavl State Technical University, Yaroslavl, Russian Federation

Abstact. An important step in improving the efficiency of crop production is the development of scientifically valid technologies and technical means of presowing preparation and treatment of seeds. Among the various methods that have a positive impact on crop growth, early maturity and resistance to adverse conditions, one of the most promising is seed pelleting. (*Research purpose*) The reasonability of the use of pelleted seeds (dragees) was shown the shell composition of which includes the substances necessary for active growth and increase resistance to adverse effects, and, in addition, it provides a more accurate seeding. We substantiate the need for improvements to existing technologies and agricultural equipment (for example, seed pelleting machine). due to the significant lack of hightech means of mechanization of seed presowing preparation at domestic agricultural enterprises. (*Materials and methods*) Experimental studies have been carried out with the use of computer mathematical modeling. Results of experiments were processed by methods of mathematical statistics, statistical analysis and data processing package, research application package, filtering, analysis and modeling of technological processes. Physical and mechanical properties and quality indicators of seeds and fillers have been determined in accordance with the applicable state standards. (*Results and discussion*) Use has been made of a program that includes obtaining information about the processes to solve the problems of experimental studies carried out by machines for pre-sowing treatment of seeds in accordance with the developed models of their functioning; the choice of the most effective means of measuring, recording and processing information about the operation of machines and equipment in normal operating conditions; as well as checking the effectiveness of the developed methods and tools to ensure the quality of the process in case of accidental disturbances. (*Conclusions*) The authors have studied main parameters and operating modes of a seed pelleting installation. An average values of the process parameters of the presowing treatment of seeds have been calculated under the conditions of normal functioning of machinery and equipment taking into account the validity and reliability of the obtained characteristics. The authors have developed the technological fundamentals of the artificial coating of seed surface. The study results can be used as practical recommendations for the organization of presowing treatment of seeds in order to increase seed germination and crop yields.

Keywords: information model, operations model, improving of presowing treatment, technological process, seed pelleting, production line.

For citation: Kubeyev E.I., Antropov B.S. Decomposition of technological processes for evaluating the performance of production line for the presowing treatment of seeds. *Sel'skokhosyaystvennye mashiny i tekhnologii.* 2018. 12(3): 18-22. DOI 10.22314/2073-7599-2018-12-3-22-27. (In Russian)

Pre-sowing treatment of seeds is preceded by a preparatory period, one of the tasks of which is to study the theoretical foundations of the operation of a pelleting installation, to work out a technique for processing experimental data and to interpret the results obtained. For this purpose, experiments have been carried out using the computer simulation method. In general, the technological process using various mathematical methods can be represented as a relation between the input $x_1(t)$, ... $x_n(t)$ and the output parameters $y_1(t)$, ... $y_k(t)$ [1-3].

Research of purpose is to improve the methods and means of experimental studies of the pre-sowing treatment including the study of the scheme, probabilistic characteristics and models of the functioning of pre-sowing seed treatment; mathematically represent the relationship between the input and output parameters of the technological process of pre-sowing seed treatment to determine unknown dynamic characteristics.

Materials and methods. The dynamic characteristic of the technological process of pre-sowing seed treatment can be represented as an unknown linear system [1]. It is advisable to consider it as an element that determines the relationship between the input and output parameters of the technological process (Fig. 1).

Research results. The information model of technological processes of pre-sowing seed treatment and the quality evaluation of their functioning can be represented in the form of the following structurally interconnected systems (Fig. 2) [4].

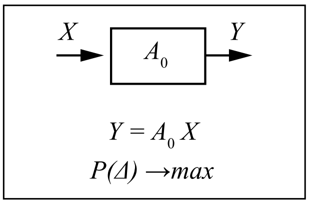

Fig. 1. General informational model with quality criterion

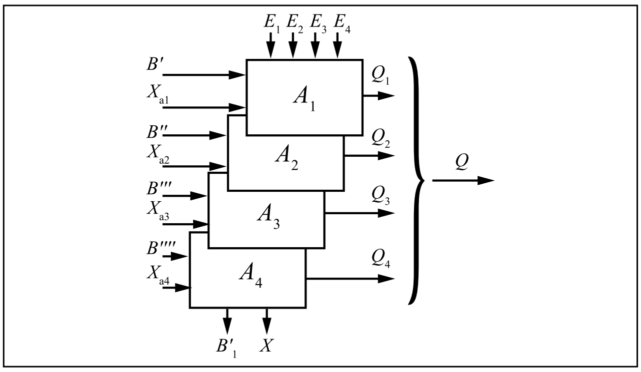

Fig. 2. Information model of technological processes evaluation of pre-sowing preparation and seed treatment

The optimization problem is reduced to maximizing the probability of maintaining the tolerance of the quantitative and qualitative parameters of each of the stages of the technological processes Q, where the selection of the vector of controlled parameters of the machine is represented as (X_{a1}, X_{a2}).

Because of the interference E_i, the tolerance preservation function may change, so we can speak about the maximization of its mathematical expectation.

$$Q_{cp} = \left[X_{a1}, X_{a2},..., E_1, E_2,...B', B''...\right] = \\ = M\left[X_{a1}, X_{a2},..., E_1, E_2,...B', B''...\right] = \\ = \int_{E\in\Omega}^{E\in\Omega} A_i \left[X_{a1}, X_{a2},..., E_1, E_2,...B', B''...\right] P(E)\, dE, \qquad (1)$$

where A_i is the transformation operator of the input vectors to the output ones; X_{a1}, X_{a2} ... – a set of machines for preparatory-and-final operations;

E_1, E_2 ... are the interference vectors determined by the properties of seeds and shell components; B', B'' – preparatory-and-final operations.

The procedure of multiparametric optimization is reduced to finding vectors X (one of the variants of preparatory-and-final operations) that satisfy the inequalities:

$$d_{js}\left[(X_{a1}, X_{a2},...)(E_1, E_2,...)(B', B'',...)\right] \geq Q, \qquad (2)$$

$$Q^* < Q\left[(X_{a1} X_{a2},)(E_1, E_2,...)(B', B'',...)\right] < Q^0, \qquad (3)$$

where Q^0, Q^* – a given level of the system quality and its minimum value, respectively.

Maximizing the probability of maintaining the tolerance does not involve achieving a maximum by all its components, which can take definite values and characterize the properties of the system.

It is generally accepted that the actual generalized system for estimating the probability of maintaining the tolerance Q^0 and a set of values of the additional estimated indicators q^+_e are less than or equal to the values of Q^0 and q^0 (parameters that satisfy the imposed constraints), and q^0_e may not reach extreme values.

Variants of technological processes for the preparation of seeds, protective-stimulating components and adhesive liquid can be expressed as:

$$\left\{\begin{matrix} Q_1^0 \leq Q_{1доп}^0 \\ Q_2^0 \leq Q_{2доп}^0 \\ Q_3^0 \leq Q_{3доп}^0 \\ \\ q_1^0 \leq q_{1доп}^0 \\ q_2^0 \leq q_{2доп}^0 \\ q_3^0 \leq q_{3доп}^0 \end{matrix}\right\}. \qquad (4)$$

Compliance with these conditions requires that all operations should be performed observing agrotechnical requirements and ensuring necessary quality.

The tolerance for the current value of the output process (or operation) under the influence of random disturbances can be preserved if the input perturbations correspond to the tolerances. They were taken into account in making up a set of machines and equipment as dynamic systems. Thus, if the characteristics of the input perturbations and the operating modes of machines and equipment do not correspond to those permissible, the issue of maintaining the tolerance of the output technological process is incorrect as such. The maintenance of the output process tolerance $Y(t)$ depends on the mode of operation of machines and equipment U and the tolerance $\Delta^{вх}_{x}$ on the current value of the input process $X(t)$:

$$\Delta_y^{вых} = f(U, \Delta_x^{вх}). \qquad (5)$$

In the case of a functional statistical connection between the input and output processes, the problem of estimating and maintaining the current tolerances of technological processes is solved in [4, 5].

The problem of estimating and maintaining the allowed values of output technological processes becomes especially difficult when the connection between the input and output processes is dynamic and is described by differential equations, and the tolerance fields are formed by random time functions (Fig. 3).

If input disturbances enter the input of dynamical systems, they are random time functions with their estimates of statistical characteristics: average values of $m(t)$, variances D_x, probability density densities $f(x)$,

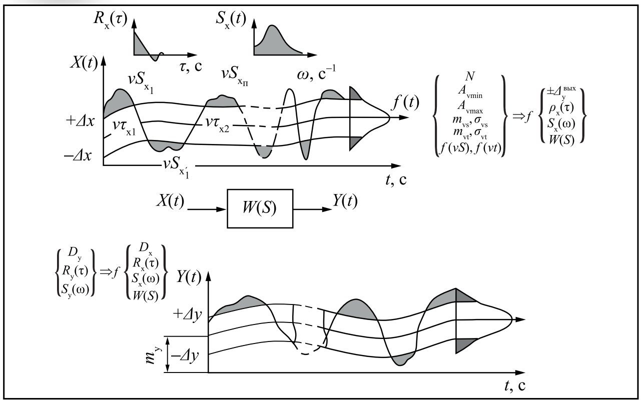

Fig. 3. Scheme of evaluation of permissible values of output processes in the dynamic functional relationship between the input and output processes of the machine

correlation functions $R(\tau)$ and their spectral densities $S(\omega)$, the following entry is valid:

$$\begin{Bmatrix} D_y \\ R_y(\tau) \\ S_y(\omega) \end{Bmatrix} \Rightarrow f \begin{Bmatrix} D_x \\ R_x(\tau) \\ W(S) \end{Bmatrix}, \qquad (6)$$

where D_y, $R_y(\tau)$, $S_y(\omega)$ are the dispersion, the correlation function and the spectral density of the output process, respectively.

In accordance with expression (6) we obtain:

$$\begin{Bmatrix} N \\ A_{v\min} \\ m_{vs}, \sigma_{vs} \\ m_{vt}, \sigma_{vt} \\ f(vS), f(vt) \end{Bmatrix} \Rightarrow \begin{Bmatrix} \pm\Delta_y^{вых} \\ \rho_x(\tau) \\ S_x(\omega) \\ W(S) \end{Bmatrix}, \qquad (7)$$

where $\pm\Delta^{вых}_y$ – tolerance for the current value of the output process; N – quantity of emissions for the established random level; A_{vmin} and A_{vmax} – the minimum and maximum ejection values, respectively; m_{vS}, σ_{vS}; m_{vt}, σ_{vt} – parameters of the mean value and the standard deviation of the square and duration of the outburst, respectively; $f(v_S)$, $f(v_t)$ are the values of the probability density of the distribution of the areas v_S and the duration of the emissions v_t, respectively.

When preparing seeds and other components for the process of artificial coating due to a change in their physical-and-mechanical properties, and also depending on the performance of the corresponding plants, the load mass $m_c(t)$, $m_n(t)$, $m_k(t)$ is transformed into the delivery mass $q_n(t)$, $q_k(t)$, respectively. At the preliminary stage of artificial coating, due to the interaction of the seeds $q_c(t)$ and the adhesive liquid $q_n(t)$, the physical-and-mechanical properties os the seeds change, which leads to a change in their rolling speed along the inner surface of the drum $v_c(t)$. At sufficiently high rolling speed (without detaching from the surface), the delivery

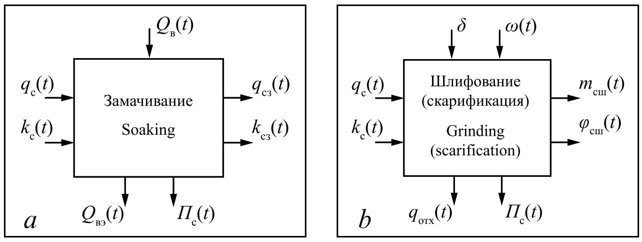

Fig. 4. Pre-sowing seed treatment model: a – soaking, b – grinding

of the filler $q_k(t)$ ensures the coagulation of the filler with the surface of seeds and their output with the artificial coating $q_d(t)$ [6-8].

For example, when treating seeds of essential oil plants before sowing, they are soaked instead of grinding, (Fig. 4) in order to remove (dissolve) the essential (etheral) shell containing inhibitory substances, in addition, the seeds undergo fermentation. To dissolve the essential (etheral) shell, it is necessary to change the water used for grain soaking. In this process, the loss of $\Pi_c(t)$ seeds is possible during the replacement of water [9-11].

When the artificial coating is applied in advance, grinding is typically performed (Fig. 4).

To ensure the required quality of the technological process, it is necessary to establish the required gap δ between the drum and plates and the speed $\omega(t)$. It should be noted that together with the waste $q_{max}(t)$, seed losses $\Pi_c(t)$ are possible.

Taking account of the above-mentioned facts, a model has been made for the functioning of technological processes of the preparation of seeds and other components and their treatment by the application of artificial coating (Fig. 5).

Calculation of permissible values to estimate the performance of machines for pre-sowing treatment of seeds.

To assure the quality of technological processes involved in the preparation of seeds for sowing, it is necessary to identify their quantitative estimates.

Proceeding from the above-mentioned requirements and provided that the studied processes are random variables with the properties of stationarity and ergodicity, tolerances $\pm\Delta_x$ on their time duration can be used as such estimates.

The probability of maintaining tolerance (quantitative assessment of the quality of processes during pre-sowing treatment) is defined as:

$$P_\Delta = \int_{-\Delta_x}^{+\Delta_x} f(x)dx, \qquad (8)$$

where $f(x)$ is the distribution density of the parameters x.

The distribution of these parameters differs from the normal one, but calculating the acceptable values of the quality of technological processes and the pre-sowing treatment, their distribution can be considered normal. With such a distribution pattern of parameters,

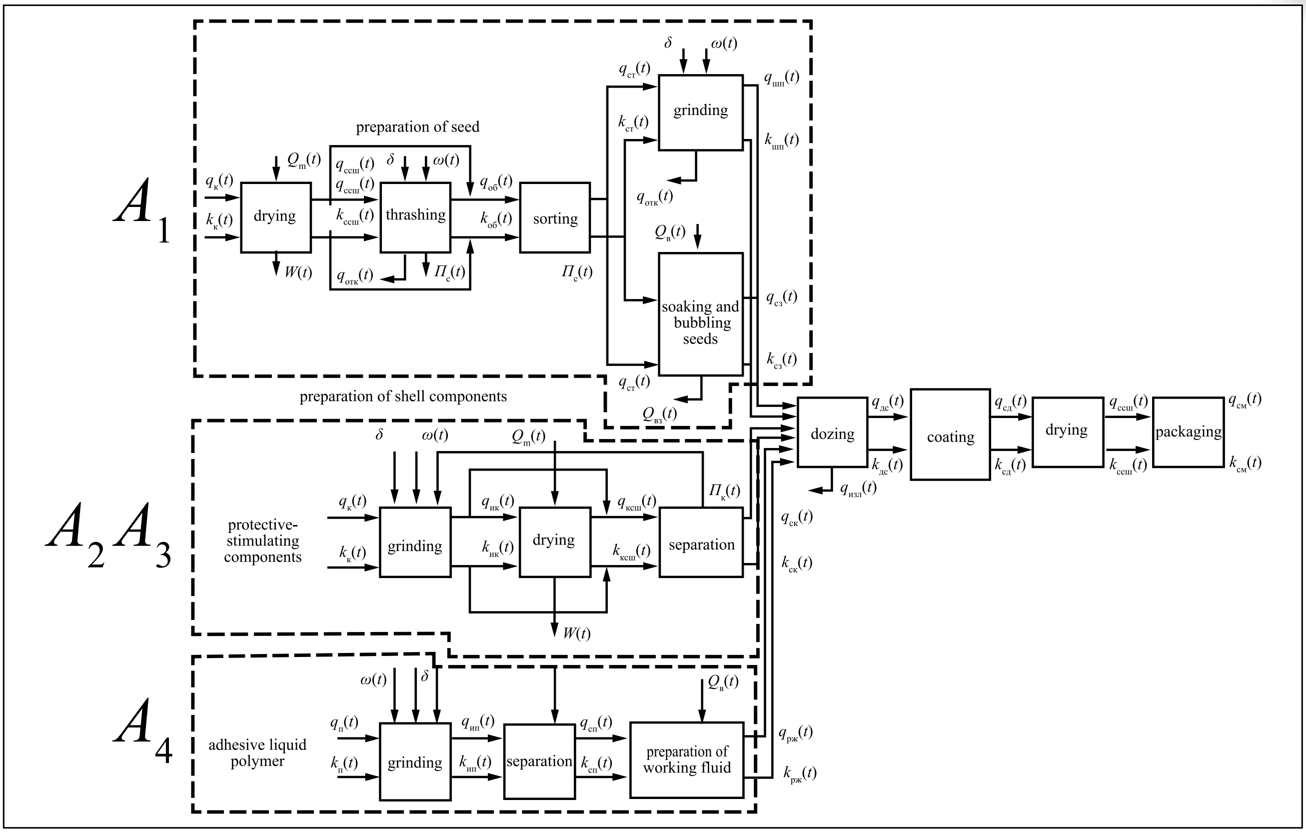

Fig. 5. Model of functioning of technological process of drawing artificial covers

relation (8) is reduced to the form:

$$P(-\Delta x < x < +\Delta x) = \Phi\left(\frac{\Delta x - m_x}{\sigma_x}\right) - \Phi\left(\frac{m_x - \Delta x}{\sigma_x}\right), \quad (9)$$

where $\Phi(x)$ is the Laplace function,

$\dfrac{\Delta - m_x}{\sigma_x}$ – the normalized value of the argument.

With a symmetrical deviation of $\pm\Delta_k$ relative to the mean value of m_x, the possibility of developing an evaluation of the process quality with a probability P in the interval $\pm\Delta_x$ is determined as follows: if the interval Δ_{x1} and Δ_{x2} is symmetric with respect to the scattering center and $\Delta_{x1} = m_x - \Delta_x$, and $\Delta_{x2} = m_x - \Delta_x$, formula (9) takes the form:

$$P\left(\left|x - m_x\right| < \Delta_x\right) = \Phi\left(\frac{\Delta_{x1}}{\sigma_x}\right) - \Phi\left(\frac{\Delta_{x2}}{\sigma_x}\right), \quad (10)$$

and since $\Phi(k)$ is an uneven function, the equation will have the form:

$$P\left(\left|x - m_x\right| < \Delta_x\right) = 2\Phi\left(\frac{\Delta_x}{\sigma_x}\right) \quad (11)$$

or

$$P\left(\left|x - m_x\right| < \Delta_x\right) = 2\Phi\left(\frac{\delta_x}{v_x}\right), \quad (12)$$

where Δ is the functional tolerance for deviation,

$$\delta_x = \Delta_x / m_x - 1 \left[(\Delta_x - m_x) / \sigma_x = \frac{m_x\left(\frac{\Delta_x}{m_x} - 1\right)}{\sigma_x} \right],$$

the relative diameter of the pellets obtained, expressed in %;

$v_x = \left(\sigma_x / m_x\right)$ – the coefficient of variation.

Here m_k is the average value of the diameter of the obtained pellets, *mm*, (as a measure of the quantitative evaluation of the technological process quality).

Conclusions

The criterion for optimizing the processes for pre-sowing seed treatment will be the probability of maintaining the tolerance for this process, therefore, the higher the probability of maintaining the tolerance is, the more stringent technological requirements must be met by the entire technological process of pre-sowing seed treatment and the performance quality of each machine.

Expressions (11) and (12) have been used to determine the probability of maintaining the specified tolerances $\pm\Delta_x$ from the results of experimental studies of the processes of artificial coating after determining their numerical characteristics-the mean value of m_x and the standard deviation m_x and calculating their acceptable values for a given value of δ_x.

Due to the statistical nature of the processes of pre-sowing seed treatment under conditions of normal functioning of machines and equipment, , the average values of these parameters were calculated to estimate the parameters taking into account the validity and reliability of the characteristics obtained.

After making limitations on P_{Δ}, the obtained characteristics have been used to determine the acceptable values in view of agrotechnical requirements for pre-sowing seed treatment and the quality of machinery and equipment.

Taking into account the above-mentioned conclusions, the criterion for increasing the efficiency of technological processes in the application of artificial casings should be an increase in the probability of maintaining the tolerance $P(\Delta) \Rightarrow max$ of the quality indices of technological processes, namely, the angle of friction and seed supply; concentration and supply of adhesive liquid; granulometric composition and supply of protective-stimulating components; pneumotransporting speed of protective and stimulating components; kinematic mode of the deposition of artificial coatings.

The disaggregation of the structural model of the technological process of pre-sowing seed treatment (Fig. 2) into components (Fig. 4 and 5) has allowed to establish a set of technological processes; the quantitative characteristics and dynamics of their flow significantly affect the process of pre-sowing seed treatment as a whole. This set includes the following processes: preparation of seeds, adhesive liquid, protective-stimulating components and fillers, as well as ensuring their interaction with the purpose of their layering and coagulation to form an artificial coating.

REFERENCES

1. Modelirovaniye sel'skokhozyaystvennykh agregatov i ikh sistem upravleniya [Modeling of agricultural units and their control systems] /Ed. by A.B. Lur'ye. L.: Kolos. 1979. 312. (In Russian).
2. Valge A.M., Pashchenko F.F. Matematicheskoye modelirovaniye tekhnologicheskikh protsessov sel'skokhozyaystvennogo proizvodstva po eksperimental'nym dannym (Dinamicheskiye modeli): Metodicheskiye rekomendatsii [Mathematical modeling of technological processes of agricultural production according to experimental data (Dynamic models): Guidelines] NIPTIMESKH NZ RSFSR. L.: Pushkin, 1980. 85. (In Russian).
3. Valge A.M. Obrabotka eksperimental'nykh dannykh i modelirovaniye dinamicheskikh sistem pri provedenii issledovaniy po mekhanizatsii sel'skokhozyaystvennogo proizvodstva [Processing of experimental data and modeling of dynamic systems during research on agricultural production mechanization]. SPb.: SZNIIMESKH, 2002. 176. (In Russian).
4. Yenikeyev V.G., Kerber V.N., Kryachko K.A. Polucheniye pervichnoy informatsii i yeye obrabotka dlya modelirovaniya sel'skokhozyaystvennykh agregatov i ikh sistem regulirovaniya [Generation and processing of primary information for the simulation of agricultural machines and their control systems] //Zapiski LSKHI. L., 1966. Vol. 108. Issue 1: 41-46. (In Russian).
5. Yenikeyev V.G., Valge A.M., Plaksina Ye.G. Ispol'zovaniye statisticheskikh metodov dlya obrabotki dannykh pri provedenii nauchnykh issledovaniy po mekhanizatsii i elektrifikatsii sel'skokhozyaystvennogo proizvodstva [Use of statistical methods for data processing in conducting a scientific research on the mechanization and electrification of agricultural production]. L., 1978. 64. (In Russian).
6. Kubeyev Ye.I. Optimizatsiya kinematicheskogo rezhima drazhirovaniya [Optimization of the kinematic mode of pelleting] // *Agrarnaya nauka*. 2010. 7. 29-30. (In Russian).
7. Kubeyev Ye.I. Vzaimodeystviye semyan i komponentov drazhe [Interaction of seed and pellet components] //*Tekhnika v sel'skom khozyaystve*. 2010. 3. 37-39. (In Russian).
8. Kubeyev Ye.I. Uvelichit' vskhozhest' semyan morkovi [Incresing the germination rate of carrot seeds] // *Sel'skiy mekhanizator*. 2010. 8. 16-17. (In Russian).
9. Kubeyev Ye.I. Veroyatnostnaya otsenka kachestva kalibrovaniya drazhirovannykh semyan ovoshchnykh kul'tur [Probabilistic assessment of the calibration quality of pelleted vegetable seeds] //*Mekhanizatsiya i elektrifikatsiya sel'skogo khozyaystva*. 2010. 4. 26-27. (In Russian).
10. Chernoivanov V.I., Ezhevskiy A.A., Fedorenko V.F. Mirovyye tendentsii mashinno-tekhnologicheskogo obespecheniya intellektual'nogo sel'skogo khozyaystva [Global trends in machine-technological support of intellectual agriculture]. Moscow: Rosinformagrotekh. 284. (In Russian)
11. Tariq Shah, Amir Zaman Khan, Asif ur Rehman, H. Akbar, A. Muhammad, S.K. Khalil. Influence of pre-sowing seed treatments on germination properties and seedling vigor of wheat // Research in: Agricultural & Vet. Sci. 1(1): 2017. 62-70. (In English)

The paper was submitted to the Editorial Office on 01.02.2018 The paper was accepted for publication on 09.04.2018

Conflict of interest. The authors declare no conflict of interest.

CC BY

DOI 10.22314/2073-7599-2018-12-3-28-31

Proximate Design of Onion Harvester Separating Surface

Aleksei V. Sibirev,
Ph.D. (Eng.), Senior Research Engineer,
email: sibirev2011@yandex.ru;
Aleksandr G. Aksenov,
Ph.D. (Eng.), Key Research Engineer;
Aleksey S. Dorokhov, Dr.Sc. (Eng), Corresponding Member of the Russian Academy of Sciences, Chief Researcher;

Federal Research Agroengineering Center VIM, Moscow, Russian Federation

Abstract: High variability of soil and climatic conditions in Russia requires to develop and use appropriate technologies and technical means to harvest root crops. The authors have determined input parameters that depend on physical and mathematical characteristics of harvested crops, soil type and condition and have a critical impact on developing crop harvesters and harvesting technologies. (*Research purpose*) The research aims at determining the separation intensity of onion-soil heap on the rod elevator, as well as onion heap supply from the surface of the rod elevator trails to the secondary separation mechanisms – all relating to onion harvesting machines. (*Materials and methods*) The size and mass parameters of the studied material are limitative for designing basic parameters of the working elements of technical equipment. The issue of increasing quality indicators of onion picker separators is considered on condition that basic input parameters should be precisely defined as they determine technological process of onion cleaning from soil and plant impurities. The authors have determined the amount of onion heap supply to the onion harvester lifting share in accordance with onion dimensional and mass characteristics. (*Results and discussion*) The onion fraction in the total lifted heap has been determined as well as the weight of onion heap and impurities on the rod elevator trails and onion heap supply from the surface of the rod elevator trails to the secondary separation mechanisms. The authors have also specified separation intensity as well as interdependencies describing a possibility of loss prevention in onion heap fractional composition passing through the rod elevator slots. The influence of design and technical parameters of the rod elevator as well as the influence of fine soil fraction mass on the onion heap separation intensity of the rod elevator have been revealed as well. (*Conclusions*) The formula has been obtained to determine onion heap supply from the rod elevator surface to the secondary separation mechanisms depending on design and technical parameters of the rod elevator as well as the onion heap weight.
Keywords: onion; onion harvesting; clumped soil; heap supply; heap fractions; separation intensity.

For citation: Sibirev A.V., Aksenov A.G., Dorokhov A.S. Proximate design of onion harvester separating surface: *Sel'skokhozyaystvennye mashiny i tehnologii*. 2018; 12(2): 23-25. DOI 10.22314/2073-7599-2018-12-3-28-31. (In Russian)

The development of industrial production of seed onion is restrained by the lack of means for mechanically harvesting bulbs that meet one of the agrotechnical requirements - the complete separation of the heap of bulbs from soil impurities [1, 2]. In addition, due to the increase in the yield of seed onion using high-yielding hybrids as a seed material (Hercules F1, Sturon, Troy F1, Shtur BS 20, Centurion F1, Forum F1, Globus, Zolotnichok), the mass and the number of seed onion bulbs are increased for one running meter [3].

Consequently, the supply of a heap of bulbs from the surface of digging devices to the separating working elements of primary and secondary separation of modern harvest harvesting machines is increased, which do not ensure the complete removal of soil impurities in the harvesting of onion.

The quality of the technological process performance of a machine for onion harvesting is primarily determined by the work of the digging working element. Depending on its type and technological parameters, the design and technological parameters of the separating devices may change [4-7].

The peculiarities of the change in the intensity of separation of the tuberous heap in a potato harvester have been revealed [8]. But potato tubers and seed onion bulbs have different size-mass and physical-and-mechanical properties. Therefore, when calculating the separating devices for onion bulbs, it is necessary to clarify the corresponding empirical coefficients and analytical dependencies.

Research purpose – determination of the intensity of separation of the onion-soil heap on the rod elevator, and the amount of heap passed from the surface of the rod elevator to the secondary separation devices as exemplified by machines for onion harvesting.

Materials and methods. To determine the amount of onion bulb heaps passing from undercutting working elements to the separating elements of a harvesting machine, it is necessary to provide laboratory conditions identical to the real ones when cultivating onions.

Results and discussion. The proportion of bulbs $W_л$ in relation to the total volume of the onion-soil heap is determined from the expression [9]:

$$W_{\text{Л}} = \frac{V_{\text{Л}}}{V_{\text{В}}}, \tag{1}$$

where $V_{\text{л}}$ – volume of bulbs, dug by a share, m^3;

$V_{\text{В}}$ – the volume of the onion-soil heap dug by the share, m^3.

The supply of an onion heap $Q_{\text{Вп}}$ onto a digging share is found from the expression [10]:

$$Q_{\text{Вп}} = \frac{V_{\text{В}} v_{\text{л}} (\rho_{\text{П}} + \rho_{\text{л}})}{l_{\text{П}}}, \tag{2}$$

where $v_{\text{л}}$ is the translational velocity of the digging share, *m/s*;

$\rho_{\text{п}}$ – soil density, *kg/m³*;

$\rho_{\text{л}}$ – the density of bulbs, *kg/m³*;

$l_{\text{п}}$ – the length of digging share, *m*.

Thus, with a known scheme of onion cultivation, the amount of heap inflow on the digging share can be determined by formula (2), taking into account the physical-and-mechanical properties of soil and bulbs.

The composition of the onion heap $m_{\text{вп}}$, coming from the surface of the digging working element to the separating elements is formed by five main fractions (by weight, *kg*):

- fine soil impurities m_1;
- soil clumps that are equal to bulbs in size m_2;
- large soil clumps m_3;
- bulbs m_4;
- plant impurities m_5.

The working surface of the rod elevator is formed by a set of bars with a diameter $d_{\text{П}}$ with a slot distance between them $S_{\text{П}}$, due to the implementation of the separation process in accordance with the conditions [4]:

- maximum sifting of soil and other impurities;
- reduction to a minimum of losses and damage of root crops.

The implementation of the first condition requires increasing the clearance in the elevator and the intensity of the impact on the heap components. The second condition assumes narrowing of the gaps and a partial load mode of operation. According to the technological scheme of the machine for harvesting root crops and onion, the primary separation devices are designed to separate small soil impurities m1, therefore slotted holes to prevent losses of marketable products are selected from the condition:

$$S_{\text{П}} < d_{\text{К}}, \tag{3}$$

where $d_{\text{К}}$ is the minimum diameter of the root crop, *m*.

Consequently, the fractional composition of seed onion heap- at the $m_{\text{СХэл}}$ descent from the rod elevator consists of:

- clumps of soil equal in size with bulbs, m_2;
- large soil clumps, m_3;
- bulbs, m_4.

It is possible that the bulb intersects the surface of the rod elevator parallel to its bars (Fig.).

The probability of this event [4]:

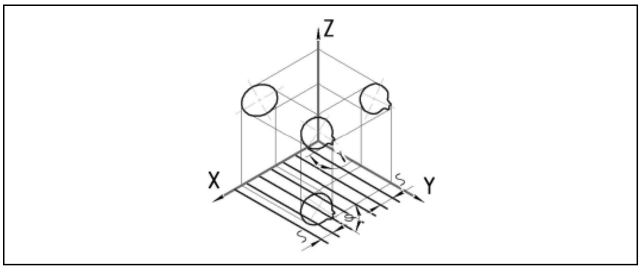

Fig. Diagram to possibility determination of onion penetration through rod elevator blanks

$$P = \frac{8}{\pi^2 S} \int_{\varphi_1}^{\varphi_2}\int_{\gamma_1}^{\gamma_2} \frac{d_{\text{к}} \sin\varphi \sin\gamma - S_{\text{П}}}{2} d\varphi d\gamma, \tag{4}$$

where φ is the angle between the horizontal projection of the bulb and the bars of the elevator, *deg.*;

γ – the angle between the vertical projection of the bulb and the elevator rods, *deg.*

Wherein:

$$\varphi_1 = \arcsin\frac{S_{\text{п}}}{d_{\text{к}} \sin\gamma}; \tag{5}$$

$$\varphi_2 = \arcsin\frac{2S_{\text{п}}}{d_{\text{к}} \sin\gamma}; \tag{6}$$

$$\gamma_1 = \arcsin\frac{S_{\text{п}}}{d_{\text{к}} \sin\varphi}; \tag{7}$$

$$\gamma_2 = \arcsin\frac{2S_{\text{П}}}{d_{\text{К}} \sin\varphi}, \tag{8}$$

where γ_1, φ_1 are minimal, and γ_2 and φ_2 are the maximum values of the parameters.

The probability $P'$of excluding losses of the fractional composition of onion heap (m_2, m_3, m_4) through the slots of the rod elevators is determined by the expression [4]:

$$P' = \frac{\pi - 2\eta_2}{\pi} + \frac{2d_{\text{К}}}{\pi^2 S_{\text{П}}}(\eta_2 - \eta_1) - \\ - \frac{d_{\text{К}}}{\pi^2 S_{\text{П}}}(\sin 2\eta_2 - \sin 2\eta_1) - \frac{4}{\pi^2}(\eta_2 - \eta_1), \tag{9}$$

where:

$$\eta_1 = \arcsin\sqrt{\frac{S_{\text{П}}}{d_{\text{К}}}}; \tag{10}$$

$$\eta_2 = \arcsin\sqrt{\frac{2S_{\text{П}}}{d_{\text{К}}}}., \tag{11}$$

where η_1, η_2 are the limits of the variation of the angles φ and γ, which are favorable for this event.

Fractions of bulbs, large soil clumps and clumps equal in size with bulbs come off from the separating surface of the rod elevator. Therefore, the mass of onion heap coming out of the rod elevator is:

$$m_{\text{СХэл}} = (m_2 + m_3 + m_4)\,P'. \tag{12}$$

Let us calculate the probability of passing of P'_{Π} mass $m_{\text{СХэл}}$ through slots S_{Π} of the rod elevator:

$$P'_{\Pi} = 1 - P'. \tag{13}$$

According to formula (12), we obtain the mass of onion heap at the $m_{\text{СХэл}}$ descent from the surface of the rod elevator:

$$m_{\text{СХэл}} = 2P'(m_2 + m_3 + m_4) - (m_2 + m_3 + m_4). \tag{14}$$

The mass of the separated fine soil fraction m_1 can be found from the expression:

$$m_1 = m_{\text{Вп}} - m_{\text{СХэл}}, \tag{15}$$

where $m_{\text{Вп}}$ is the mass of an onion heap coming from digging to separating working elements, *kg*:

$$m_{\text{Вп}} = \frac{Q_{\text{Вп}}\, l_{\Pi}}{v_{\text{л}}}. \tag{16}$$

With the known supply of an onion heap on a digging share $Q_{\text{Вп}}$, we determine the intensity of the separation of the onion bulb heap on the surface of the rod elevator of the harvesting machine $q_{\text{В}}$. In accordance with [11, 12], we refine the well-known formula according to the expression (12):

$$q_{\text{В}} = \frac{m_1\, v_{\text{ЭЛ}}}{B\, l^2_{\text{ЭЛ}}}, \tag{17}$$

where $v_{\text{эл}}$ is the translational speed of the rod elevator, *m/s*;

B – the width of the rod elevator, *m*;

$l_{\text{эл}}$ – the length of rod elevator, *m*. The amount of feeding a bulb heap from the surface of the rod elevator to the secondary separation devices is determined by the formula:

$$Q_{\text{Вэл}} = \frac{m_{\text{СХэл}}\, v_{\text{ЭЛ}}}{l_{\text{ЭЛ}}}. \tag{18}$$

Conclusions. The results of the conducted studies allow to determine the intensity of the separation of bulbs, the amount of feeding of bulbs from the surface of the rod elevator to the secondary separation devices with respect to machines for onion harvesting. These indicators are the determining factor in the design of the secondary separation devices.

REFERENCES

1. Izmaylov A.Yu., Lobachevskiy Ya.P. Sistema mashin i tekhnologiy dlya kompleksnoy mekhanizatsii i avtomatizatsii sel’skokhozyaystvennogo proizvodstva na period do 2020 goda [System of machinery and technologies for integrated mechanization and automation of agricultural production for the period up to 2020] // *Sel’skokhozyaystvennyye mashiny i tekhnologii*. 2013. N6: 6-10. (In Russian)

2. Lobachevskiy Ya.P., Yemel’yanov P.A., Aksenov A.G., Sibirev A.V. Mashinnaya tekhnologiya proizvodstva luka: Monografiya [Machine technology of onion production: Monograph]. M.: VIM. 2016: 168. (In Russian)

3. Aksenov A.G., Sibirev A.V. Issledovaniye razmerno-massovykh kharakteristik luka-sevka gibrida Gerkules F1 [Study the dimensionmass characteristics of Hercules F1 hybrid onion] // *Vestnik Kazanskogo GAU*. 2016. N2(40): 5-9. (In Russian)

4. Khvostov V.A., Reyngart E.S. Mashiny dlya uborki korneplodov i luka (teoriya, konstruktsiya, raschet) [Root crop and onion harvesters (theory and design)]. M.: 1995: 391. (In Russian)

5. Aldoshin N.V., Didmanidze O.N. Inzhenerno-tekhnicheskoye obespecheniye kachestva mekhanizirovannykh rabot: Monograpfiya [Engineering and technical support of the quality of mechanized works: Monograph]. M.: RGAU-MSKhA. 2015: 188. (In Russian)

6. Aldoshin N.V. Stabil’nost’ tekhnologicheskikh protsessov v rasteniyevodstve [Consistency of technology processes in crop production] // *Mekhanizatsiya i elektrifikatsiya sel’skogo khozyaystva*. 2007. N3: 5-7. (In Russian)

7. Aldoshin N.V. Analiz tekhnologicheskikh protsessov v rasteniyevodstve [Analysis of technological processes in crop production] // *Tekhnika v sel’skom khozyaystve*. 2008. N1: 34-37. (In Russian)

8. Sorokin A.A. Teoriya i raschet kartofeleuborochnykh mashin: Monografiya [Theory and design of potato harvesters: Monograph]. M.: VIM. 2006: 158. (In Russian)

9. Kostenko M.Yu., Kostenko N.A. Veroyatnostnaya otsenka separiruyushchey sposobnosti elevatora kartofeleuborochnoy mashiny [Probabilistic estimation of the separating capacity of the potato harvesting machine elevator] // *Mekhanizatsiya i elektrifikatsiya sel’skogo khozyaystva*. 2009. N12: 4. (In Russian)

10. Sibirev A.V. Analiticheskoye opredeleniye velichiny podachi vorokha luka¬sevka na podkapyvayushchiy lemekh [Analytical determination of the amount of seed onion heap supply to a lifting share] // *Agrarnyy nauchnyy zhurnal*. 2017. N5: 75-78. (In Russian)

11. Latyshenok M.B., Goryachkina I.N., Kostenko M.Yu. Rezul’taty issledovaniya intensivnosti separatsii na laboratornom prutkovom elevatore pri regulirovanii zagruzki [Analysis results of the separation intensity of a lab raddle elevator with adjustable load] // *Vestnik Ryazanskogo gosudarstvennogo agrotekhnologicheskogo universiteta imeni P.A. Kostycheva*. 2010. N5: 70-72. (In Russian)

12. Thompson A.K. Post-harvest Technology of Fruit and Vegetables. Berlin: Blackwell Science.1996: 282. (In English)

The paper was submitted to the Editorial Office on 10.09.2017 The paper was accepted for publication on 02.06.2018

Conflict of interest. The authors declare no conflict of interest.

CC BY

DOI 10.22314/2073-7599-2018-12-3-32-37

The Efficiency of Automated Control Microprocessor Systems for LED Irradiation Installations

Nadezhda P. Kondratieva[1]**,** Dr.Sc. (Eng), Professor, Head of the Department, , email: aep_isha@mail.ru;
Roman I. Korepanov[1]**,** Postgraduate Student;
Ilnur R. Ilyasov[1]**,** Postgraduate Student;
Roman G. Bolshin[1]**,** Ph.D. (Eng), High School Teacher;
Maria G. Krasnolutskaya[1], High School Teacher;
Yelena N. Somova[2]**,** Senior Research Associate;
Marina G. Markova[2]**,** Research Associate

[1]Izhevsk State Agricultural Academy, Izhevsk, Russian Federation
[2]Udmurt Scientific Research Institute for Agriculture, Izhevsk, Russian Federation

Abstract. Crop productivity is significantly affected by the dose of optical radiation. In particular, southern crops do not have enough time to ripen in a temperate climate because of decreased daylight duration. In conditions of protected soil due to low irradiance and a short daylight duration in autumn-winter months, the cultivation of fully developed plants is possible only with the use of artificial radiation sources. The use of LED phytoinstallations with the help of microprocessor-based automatic control systems allows obtaining the required dose of optical radiation. (*Purpose research*) To substantiate, as exemplified by meristematic grape plants, the effectiveness of LED phytoinstallations and their impact on the increase in the leaf surface area; to develop multicolored LED phytoinstallations; to offer new technical solutions to improve the efficiency of the microprocessor system of automatic control of LED phytoinstallations. (*Materials and methods*) the authors have carried out experiments with meristematic grape plants of RF-48 variety (in vitro) at the stages of their rooting and adaptation. The following equipment has been used: LED phytoirradiator with a changing spectrum using a microprocessor control system, "blinking" led phytoirradiator, multicolored phytoiradiator with the addition of UV LEDs. The authors have developed on the basis of microcontroller Arduino uno a microprocessor dispensing system of the spectral components of the areas of the photosynthetically active radiation to automatically control the operation of LEDbased phytoinstallations. (*Results and discussion*) it has been shown that a LED irradiator with a changing spectral composition, as compared to a luminescent irradiator, at the stage of rooting of grape microsprouts contributes to a significant increase in the leaf surface area of microplants at 100 percent rooting of sprouts. The blinking phytoirradiator and the UVLED phytoirradiator, as compared to the fluorescent ones, contributed to an insignificant increase in leaf area of plants at the adaptation stage of grape microplants. (*Conclusions*) The authors have confirmed the need to further improve the efficiency of the microprocessorbased automatic control system of LED irradiation installations.
Keywords: LED phytoinstallations, plants in vitro, microprocessor control system, LED strips.

For citation: Kondratieva N.P., Korepanov R.I., Ilyasov I.R., Bolshin R.G., Krasnolutskaya M.G., Somova E.N., Markova M.G. The efficiency of automated control microprocessor systems for the LED irradiation installations. *Sel'skokhozyaystvennye mashiny i technologii*. 2018; 12(3): 26-30. DOI 10.22314/2073-7599-2018-12-3-32-37. (In Russian)

Crop productivity is significantly affected by the dose of optical radiation. For example, southern crops fail to mature in a temperate climate because of decreased daylight duration and the sun's height angle.

The use of multi-colored LEDs, or RGB-LEDs, allows modelling the spectrum of any geographical area, and the use of microprocessor-based automatic control systems for the operation of these units allows the required dose of optical radiation to be applied. A part of the optical range actively used by plants is called photosynthetically active radiation (PAR). The PAR has a special significance in conditions of protected soil, where, due to low irradiance and a short daylight duration in autumn-winter months, the cultivation of full-fledged plants is possible only with the use of artificial radiation sources. Properly controlling of LED phytoinstallations with the help of microprocessor-based automatic control systems allows obtaining the required dose of the spectral component of the phased zone.

Of particular importance is LED lighting for plants, in vitro, the nutrition of which is not completely autotrophic. Meristem plants are grown this way. Meristem is a plant tissue that is able to intensively divide cells [1-5]. Clonal micropropagation of plants has become one of the modern forms of improving nursery farming. This method allows not only to ensure a high multiplication factor, but also to deliver the planting material from pests and a number of pathogens. Traditionally, work aimed at increasing the efficiency of microclonal propagation of plants is reduced to optimizing the composition of the nutrient medium and the cultivation conditions. However, stimulation of morphophysiological processes in plants is possible by using phytoregulatory methods [1, 2].

Numerous studies indicate a positive effect of LED lighting on farm crops.

A feature of LED-based irradiators is that the spectral composition of their light fluxes corresponds most closely to PAR [6-9]. The urgency of the work is due to the need to improve the methods of clonal micropropagation of plants and the development of energy-saving technologies for their cultivation.

Research purpose is to increase the efficiency of the microprocessor control system for the operation of various LED irradiation facilities and to study their effect on the growth of the leaf surface of meristem grape plants.

To achieve this goal, the following tasks were formulated:

- to develop various multi-colored LED phytoinstallations;
- to conduct experiments on meristem grape plants;
- to offer new technical solutions for increasing the efficiency of a microprocessor-based automatic control system for the operation of LED-phytoinstallations.

Materials and methods. The experiments were carried out in a meristem laboratory of Udmurt Research Institute for Agriculture. Cultivated in vitro grape plants of grade RF-48 during the stages of rooting and adaptation were used for the research (Fig. 1).

Fig. 1. General view of meristem plants of grape culture

Rooting of microplants in vitro was carried out in a light-room of the laboratory on a nutrient medium according to Murasige-Skog's formulation with the addition of indolyl-butyric acid (IMC) at a dose of 0.5 mg/l with a daytime duration of 16 hours and an air temperature of 23-25 °C. Adaptation of meristem plants was carried out under the same conditions in 0.5 liter containers with peat-based ground.

For irradiation, use was made of:

- LED phytoirradiator with a changing spectrum operated with a microprocessor control system (Fig. 2);

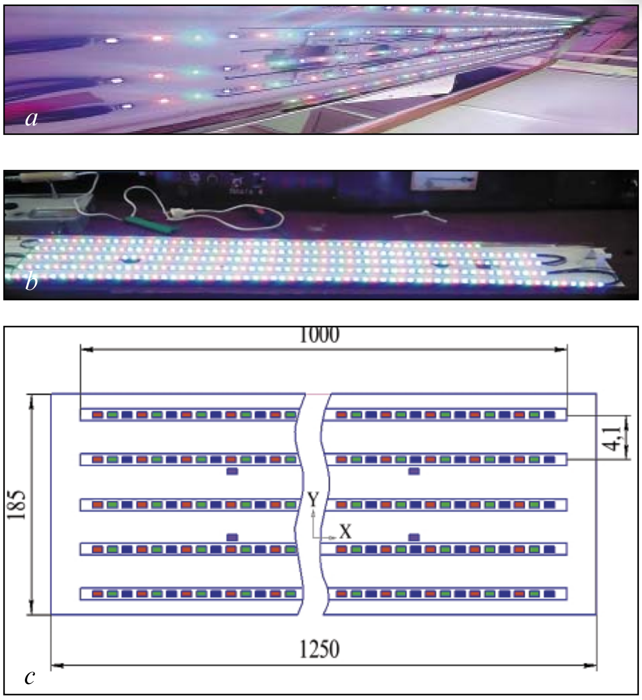

Fig. 2. LED-phyto-installation: a, b – general view; c – scheme with UV LEDs and its dimensions, mm

- "blinking" LED phytoirradiator, which shone for 0.5 s, then there was a dark pause of 1.0 s; this blinking lasted for 30 seconds and was followed by continuous irradiation for 15 seconds;
- a multi-colored phytoirradiator with the addition of UV-LEDs (Fig. 2);
- control-luminescent irradiator with an LB lamp.

Parameters of LED-phytoirradiators are given in the table.

Table

Technical characteristics of LED-phyto-radiator

Parameters	LED-phyto-radiator	LPO 2×18 (control)
Operating voltage, V	12,4	220
Power consumption, W	29,76	36
Illumination, lx	2200	1400

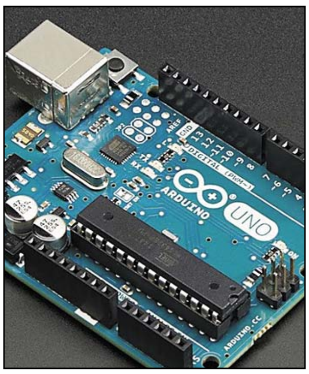

Fig. 3. Arduino Uno Board

For the automatic control of the operation of the LED phytoirradiator on the basis of the Arduino Uno microcontroller, a microprocessor system for dispensing the spectral components of the FAP zone has been developed (Fig. 3).

The principle of the automatic control system for the operation of LED phytoirradiators is described in the following reference sources [11-16].

The control program provides keys for adding cultivated crops, as well as takes into account the conditions for their cultivation.

In each variant of the experiment, 10 meristem plants were used. The area of the leaf surface was evaluated every 5 days after the beginning of irradiation. The root system of microplants was evaluated at the end of the stage by the prescribed methods (OST 10069 95).

The stage of rooting grape microsprouts was 25 days, the adaptation stage lasted for 20 days. The works on microclonal propagation were carried out according to "Technology of production of virus-free planting stock of fruit, berry crops and grapes".

The rooting stage completes the process of plant cultivation in vitro. By the end of the stage, the quality of the leaf device and the root system of the microplants can be evaluated. To successfully transfer from sterile conditions to non-sterile ones (adaptation), the imbalance between a sprout and its root system is unacceptable.

Results and discussion. The LED irradiator with a changing spectrum had a positive effect both on the area of the leaf surface of the grape microplants and root system (Fig. 4). The greatest effect was obtained on the sheet device of grape microplants. As compared to the traditional luminescent irradiator, a noticeable but insignificant increase in the leaf surface area (14.0 mm^2) was noted already on the fifth day of the rooting stage. Starting from the 10-day period and until the end of the rooting stage, this gain is statistically reliable and amounts to 39.7 mm^2, 48.9 mm^2, 61.3 mm^2, 82.9 mm^2, respectively.

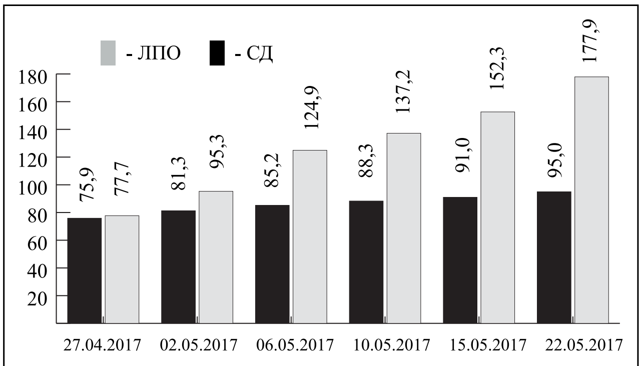

Fig. 4. The impact of lighting on the growth dynamics of leaf area of grape culture micro plants, mm^2

Rooting of grape microsprouts by the end of the stage accounted for 100% regardless of the lighting. But microplants exposed to the action of the LED irradiator featured a more developed root system. All grape microplants corresponded to OST 10 068-95 at the end of the rooting stage.

The transfer of plants from sterile to non-sterile cultivation conditions is the most critical stage of clonal micropropagation. Factors influencing the viability of microplants during the adaptation period include: the substrate type, air humidity, lighting, infectious load and others. It is at this stage that you can lose a huge amount of already propagated material.

Adapted meristem plants are planted to grow into the open ground of a nursery. A well-developed leaf system not only allows plants to take roots well, but also assists in obtaining a standard planting material by the end of the season.

According to the results of the first two five-day stages of adaptation, the irradiation of grape meristem plants with LED installations, as compared to the luminescent irradiator, did not have a significant positive effect: the leaf surface area did not increase, remaining at the level of the control values (Fig. 5).

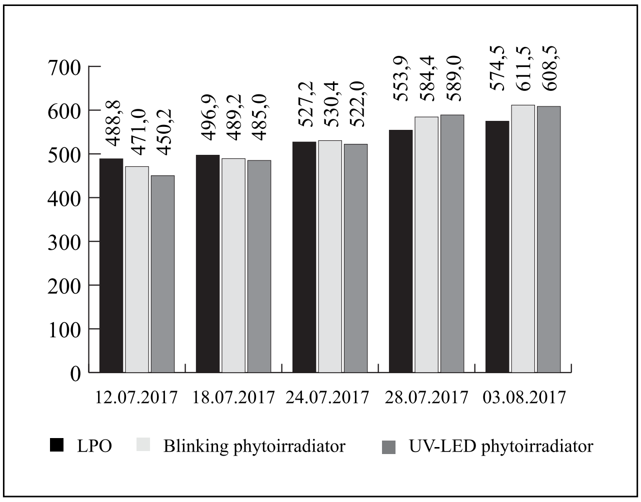

Fig. 5. The impact of lighting on the growth dynamics of leaf area of adapted grape culture micro plants, mm^2

According to measurements on the 15th and 20th days of adaptation, both LED installations, as compared to the control ones, insignificantly contributed to an increase in the grape leave area. By the end of the stage, 100% of the grape plants corresponded to OST 10 069-95.

To obtain an accurate PAR dose, it is necessary to add spectrum analyzers to the microprocessor-based automatic control system, by means of which it is possible to analyze and change the spectrum of LED-

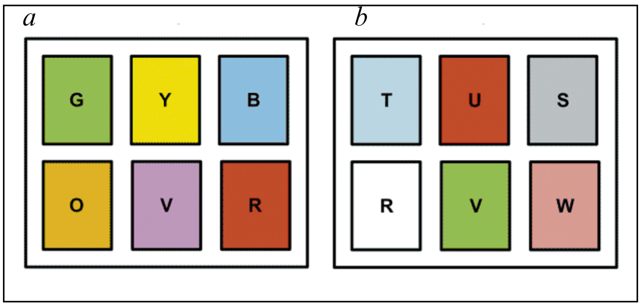

Fig. 6. Photodiode spectrum analyzers assembly: a – AS7262; b – AS7263

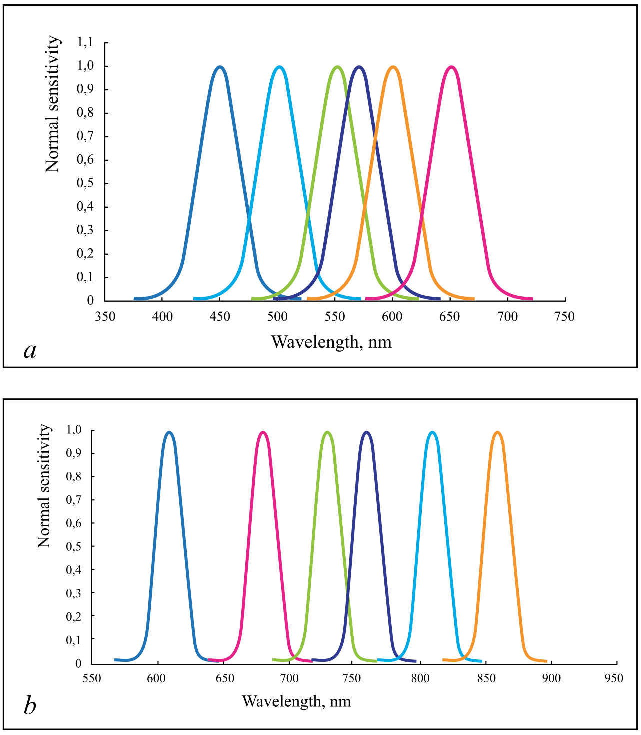

Fig. 7. The spectral sensitivity of the analyzers:
a – AS7262; b – AS7263

phytoinstallations in real time.

To solve this problem, information was found on 6-channel integrated spectrum analyzers AS7262 and AS7263. The AS7262 chip is designed to work with the visible part of the spectrum (450-650 *nm*), and AS7263 – with the infrared range (610-860 *nm*).

The key element of the AS7262 and AS7263 is photodiode assemblies (Fig. 6). In both cases they are matrices of six photodiodes with a narrow sensitivity spectrum.

The AS7262 spectrum analyzer chip is designed to work with the visible part of light (Fig. 7). Its photodiodes have a selective sensitivity of 450/500/550/570/600/650 *nm* with a spectral width of 40 *nm*. Apparently, their peak frequencies are spaced at 50 nm (with the exception of 570 *nm* orange color). The AS7263 is designed for analyzing the near-infrared range. Its photodiodes operate at frequencies of 610/680/730/760/810/860 *nm* with a sensitivity spectrum width of 20 *nm*. To develop a microprocessor system for automatic control of an LED phytoinstallation, a block diagram was developed (Fig. 8).

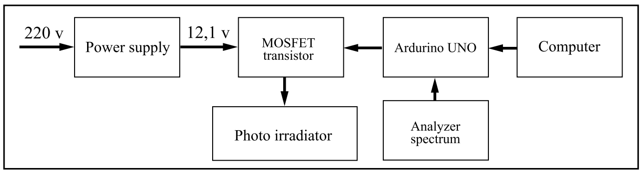

Fig. 8. The block diagram of the LED-phyto-installation control

Conclusions

1. The LED irradiator with a changing spectral composition, as compared to the luminescent irradiator, at the rooting stage of grape microsprouts contributes to a significant increase in the leaf surface area of the microplants, with their rooting being equal 100%.

2. Flashing phytoemitter and phytoembrant with UV-LEDs, as compared to luminescent ones, at the stage of adaptation of grape microplants contributed to an increase in the leaf surface area of plants, but insignificantly and only from the second half of the stage.

3. Positive results of the experiments confirmed the need to further enhance the efficiency of the microprocessor-based automatic control system for the operation of LED irradiators.

REFERENCE

1. Pronina I.N., Matushkina O.V. Economic aspects of the use of clonal micropropagation in the production system of planting material of fruit and berry crops // *Fruit growing and gourd cultivation of Russia*. 2011; 26: 82-88.

2. Markova M.G., Somova E.N. Techniques to increase the rooting microgrooves of wild strawberry in the ground NVITRO // Bulletin of the Mari State University. Series: *Agricultural sciences. Economic sciences*. 2017; 2 (10): 34-39.

3. Tertyshnaya Yu.V. Levina N.S. Vliyaniye spektral'nogo sostava sveta na razvitiye sel'skokhozyaystvennykh kul'tur [Influence of spectral composition of light on development of agricultural crops] // *Sel'skokhozyaystvennyye mashiny i tekhnologii*. 2016. N5: 24-29.

4. Tertyshnaya Yu.V. Levina N.S., Yelizarova O.V. Vozdeystviye ul'trafioletovogo izlucheniya na vskhozhest' i rostovyye protsessy semyan pshenitsy [Influence of ultraviolet radiation on the germination and growth processes of wheat seeds] // *Sel'skokhozyaystvennyye mashiny i tekhnologii*. 2017. N2: 31-36.

5. Martirosyan Yu.Ts., Polyakova M.N., Dilovarova T.A., Kosobryukhov A.A. Fotosintez i produktivnost' rasteniy kartofelya v usloviyakh razlichnogo spektral'nogo oblucheniya [Photosynthesis and the potato productivity under different spectral irradiation] // *Sel'skokhozyaystvennaya biologiya*. 2013. N1: 107-112.

6. Bolshin R.G., Ilyasov I.R., Kondratieva N.P., Korepanov R.I, Krasnolutskaya M.G., Litvinova V.M., Filatova O.M. Development of a microprocessor dosing system for photosynthetically active radiation // Bulletin of the NNIII. 2017; 9: 46-56.

7. Kondratieva N.P., Bolshin R.G., Krasnolutskaya M.G. Energy-efficient energy-saving LED irradiators // *Vestnik VIESH*. 2016; 3 (24): 48-53.

8. Il'yasov IR Increase in the effectiveness of dosing of PHAs (photosynthetically active radiation) / Ilyasov IR. // Scientific works of the students of the Izhevsk State Agricultural Academy of the Federal State Educational Establishment of the Russian Federation «Izhevsk State Agricultural

Academy». Izhevsk, 2017: 212-213.

9. Kondrat'yeva N.T., Vladykin I.R., Baranova I.A., Bol'shin R.G. Krasnolutskaya M.G., Energosberegayushchiye elektrotekhnologii i elektrooborudovaniye v sel'skom khozyaystve [Energy-saving electrotechnologies and electrical equipment in agriculture] // *Innovatsii v sel'skom khozyaystve*. 2016. N4(19): 11-16.

10. Somova E.N., Kondratieva N.P., Bolshin R.G., Krasnolutskaya M.G., Korepanov R.I., Ilyasov I.R., Litvinova V.M. Results of experiments on dosing photosynthetically active radiation by a microprocessor system controlling the operation of LED phyto-plants // *Vestnik VIESH*. 2017; 3 (28): 56-64.

11. Ilyasov I.R. Development of software for the implementation of the irradiation regime // In the collection: Scientific works of students of the Izhevsk State Agricultural Academy. The electronic resource. Izhevsk State Agricultural Academy. Izhevsk, 2017: 490-494.

12. Me Cree H.J., Joomis R.S. Photosynthsis in fluctuaning light // Ecology. 1969; 3: 50.

13. Murashige T. Plant tissue an cell culture application to crop improvement. Prauge: Czechosl. Acad. Sci., 1984: 23-32.

The paper was submitted to the Editorial Office on 24.11.2017 **The paper was accepted for publication on 07.12.2017**

Conflict of interest. The authors declare no conflict of interest.

CC BY

DOI 10.22314/2073-7599-2018-12-3-38-44

Qualitative Performance Indicators of a Ripping-and-Separating Machine for Soil Cultivation

Yury N. Syromyatnikov, postgraduate student,
e-mail: gara176@meta.ua

Kharkov National Technical University of Agriculture named after P.M. Vasilenko, Kharkov, Ukraine

Abstract. Pre-sowing soil cultivation aims at forming such a soil structure, which will allow increasing the yield. (*Research purpose*) To determine the qualitative indicators of an experimental soil-cultivating ripping-and-separating rotary machine for optimizing the ploughed soil layer, modifying the structure and density of the cultivated soil layer in accordance with the agronomic requirements. (*Materials and methods*) The author has studied physical and mechanical properties of the soil after its spring cultivation in the conditions of bare (black) fallow. Soil structure and aggregate composition depending on the type of cultivation, the density of soil layers at different times, the dynamics of soil moisture changes in the layers for two months after its spring cultivation have been analyzed as well. (*Results and discussion*) The author has studied the operation of a soil tillage ripping-and-separating machine on the soil layer, which is separated after processing into four sublayers: over-seed, seed, under-seed and subsurface ones. Soil fragments (lumps) of a size larger than 20 mm have been completely removed from the over-seed sublayer. The most valuable soil structure in agronomic terms is formed in the seed sublayer, where the size of individual components does not exceed three times the size of seeds, the density of the under-seed sublayer is up to 1.25 grams per cubic centimeter. The subsurface sublayer has a density of not more than 1.3 grams per cubic centimeter and a hardness of more than 3 MPa in the plow sole, which is provided by the main tillage operations. The information for the study has been obtained as a result of the analysis of literary sources. (*Conclusion*) The experimental machine for optimizing the agrophysical properties of the ploughed soil layer allows increasing the structural coefficient by about 2.5 times as compared with traditional cultivators. It has been found that soil cultivation with a ripping-and-separating tillage machine allows to improve the methods of pre-sowing cultivation to improve its agrotechnical characteristics, skip pre-sowing harrowing and cultivation and prepare the soil for sowing in one run.
Keywords: soil structure, layer, structure, composition, machine, surface, tillage, quality.

For citation: Syromyatnikov Yu.N. Qualitative performance indicators of a ripping-and-separating machine for soil cultivation. *Sel'skokhozyaystvennyye mashiny i tekhnologii*. 2018. 12.(3): 31-36. DOI 10.22314/2073-7599-2018-12-3-38-44. (In Russian)

Technological operations of soil cultivation by mechanical action are aimed at making favorable conditions for the accumulation and preservation of moisture, seeding, the growth and development of plants [1, 2].

Pre-sowing tillage of soil includes topsoil loosening at the depth of seeding, which provides a fine-grained structure of the seed layer, leveling the field surface, compacting the seedbed at the depth of seeding, embedding of the introduced fertilizers, eradication of germinating weeds and moisture preservation in the cultivated soil layer. Soil cultivation is also aimed at making favorable conditions for the operation of agricultural machines in sowing, cultivating and harvesting [3].

There is an experimental machine for optimizing the agrophysical properties of the ploughed soil layer, to be attached to the KhTZ-17221 tractor, Fig. 1. [4, 5].

It is used for the cultivation of cereals (winter and spring crops) and industrial crops, for performing surface and pre-sowing tillage, as well as for stubbling.

Fig. 1. The experimental soil-cultivating friable-separating machine aggregated with tractor XT3-17221

The depth of tillage when working in fields to be sown and fallows can be adjusted from 0 to 15 *cm*.

The machine (Fig. 2) consists of a chassis, a frame is attached to it by means of a parallelogram linkage mechanism, which can be moved vertically. Mounted on it are working elements: passive – legs with shares and active – a rotor with rippers. The rotor is located

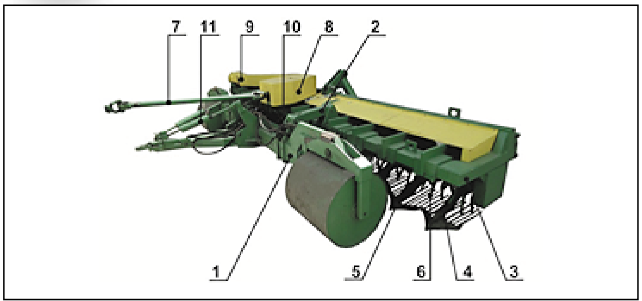

Fig. 2. Experimental soil-cultivating friable-separating machine: 1 – the chassis; 2 – the lever mechanism; 3 – frame; 4 – the rack; 5 – plowshare with separating gratings; 6 – rotor with friablers; 7 – cardan gear; 8 – gear transmission; 9 – chain transmission; 10 – mechanism for adjusting the depth of tillage; 11 – mechanism for adjusting the horizontal position of the frame

above the shares and does not touch them. The shares are provided with separating gratings.

The frame is raised and lowered by means of a hydraulic drive. The rotor is driven by the tractor's power take-off shaft via cardan, chain and gear drives. The machine is equipped with a mechanism for adjusting the depth of tillage and a horizontal positioning mechanism of the frame. The machine chassis and the circle of the hitch device are connected by means of standard mounting elements of the tractor.

The machine works as follows. When moving along the field, the shares cut the soil layer, then, when the cut layer moves along the share surfaces and the rods of the separating grating, it crumbles, and the fine crumpled fraction, which does not exceed three times the size of sown seeds, is spilt through the grating, thus forming a seed sublayer. Further formation of the seed sublayer occurs when the rotor ripper act on the layer crumbling and ripping it, thus moving it along the separating grating. The coarse-grained fraction with fragments of no more than 20 *mm* goes off the grating, forming an over-seed sublayer with parameters corresponding to the optimum water-air mode. In addition, the rotor rippers in the process of interaction with the layer comb out weeds from it, without violating their integrity, and transport them to the surface of the over-seed sublayer, and also clean the share legs from plant debris and weeds [6].

The surface quality after the main and pre-sowing cultivation is determined not only by the depth of cultivation, the surface ridgeness, stubble residues and lumpiness, but also by the structural composition and density of the cultivated layer. The last two parameters are directly related to the physical, physical-and-mechanical and rheological (plastic) properties of soil. Their values in the treated layer must meet the requirements of the sown crops [14]. Therefore, the cultivated layer must also be differentiated for different crops according to the key parameters of soil - its structural composition and bulk density.

Research purpose. Making comparative tests of the experimental soil-cultivating machine and cultivator KPS_4 with tooth harrows in operating conditions, studying the performance quality indicators of the machine.

Materials and methods. Basing on the germination and development conditions of plants, the structure of the optimal cultivated layer before sowing should meet the following requirements (Fig. 3):

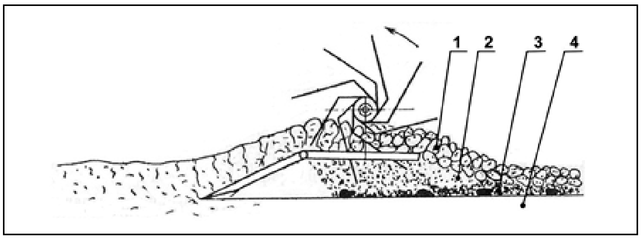

Fig. 3. Structure of the processing layer: 1 –over-seed layer; 2 – the seed layer; 3 – under-seed layer; 4 – subsurface layer

- the cultivated layer must consist of four sublayers: over-seed, seed, under-seed and subsurface ones;
- lumpy fragments of soil larger than 20 *mm* should be completely removed from the over-seed sublayer. The presence of such fragments whittle down all the advantages offered by the structure of the cultivated layer;
- in the seed sublayer, the most agrotechnically valuable structure should be concentrated, with the size of individual fragments not exceeding 3 times the size of seeds;
- the bulk density of the under-seed sublayer should not exceed 1.25 g/cm^3;
- a sub-plow sublayer should not have a density of more than 1.3 g/cm^3 and a hardness in the plow sole of more than 3 *MPa*, which is ensured by the main tillage operations [17].

The fulfillment of these requirements will ensure a good contact of the seeds with soil, their rapid swelling, germination and unhindered penetration of the roots deep into the soil, economical consumption of moisture accumulated during the autumn-winter period (due to the layered structure), and effective assimilation of nutrient elements from fertilizers by plants [16].

The granulometric composition of soil is determined by the quantitative ratio of four main fractions: sand (a particle size of 2.00-0.05 *mm*); dusty (a particle size of less than 0.002 *mm*); coarse-grained sandy loam with a particle size of 2 to 25 *mm*, and lumps with particles larger than 25 *mm* [7].

For a certain crop, the field is cultivated until the necessary looseness of soil is obtained, but in view of the reduction in energy costs. With insignificant amount of weeds, good soil condition, it is always necessary to use traditional cultivation systems, which include stubbling, plowing, and pre-sowing tillage. These methods can be replaced by soil cultivation with simultaneous sowing [8, 9]. This combined treatment is faster with the lowest energy costs and time saving.

It is known that the content of at least 40-45% of waterproof elements with a size of more than 0.25 *mm* in the plow layer ensures that the density, hardness, total porosity and aeration porosity are within optimal limits. The ploughed layer of chernozems contains 55-60% of such elements [9].

The over-saturation of the soil composition with large aggregates and lumps leads to an increase in the degree of aeration, while the predominance of dust fraction in the fine earth contributes to wind erosion. Both of these lead to the desiccation of soil and the loss of humus.

The influence of the ratio of structural soil particles and permissible standards of their content on the yield of agricultural crops is reflected in the works of V.R. Williams, P.A. Nekrasov, P.A. Piguevsky and others [10-13]. In his studies, V.V. Medvedev established the most favorable grain size composition of soil, which provides plants with nutrients and moisture. In this case, soil aggregates (granules) of 5-20 *mm* in size should be about 20-25%, agrotechnically valuable soil aggregates of 0.25-5.0 *mm* – 60-65%, and smaller than 0.25 *mm* – less than 15% [14].

With this ratio of structural soil aggregates, plants effectively use moisture and nutrients. It was also found that the maximum yield of crops was obtained with almost equal seed and soil grain size of the seed layer, and the upper layer of soil up to 4 *cm* thick should have larger soil aggregates of 5-20 *mm* in size [14].

The density of the surface layer of soil affects the development of plants during the growing season, which increases by 0.08 g/cm^3 in dry years, and decreases by 0.05 g/cm3 in wet years. Therefore, to maintain the optimal soil density in the upper layer of the ploughed horizon, it is advisable to perform compaction or loosening [14].

Studies of many scientists have shown that the soil density, hardness and porosity are optimal, when the content of agrotechnically valuable structural aggregates in the ploughed layer of soil is up to 40-45%.

To preserve moisture and lower the temperature of the soil surface, its surface is mulched with plant residues [15, 16]. Soil mulching can be done during the harvesting of crops by spreading chopped straw over the field surface.

Basing on the results of the conducted studies, it can be concluded that the most favorable conditions for plants are made by differentiating the cultivated soil layer according to its structural composition. In this case, aggregates of 5 to 20 *mm* in size should prevail in the surface layer of soil, and those from 0.25 to 10 *mm* – in the seeding zone.

Modern means of mechanization for soil tillage in mouldboard, non-mouldboard (subsurface) and minimum (reduced) tillage systems provide the necessary conditions for crop cultivation. However, to bring physical-and-mechanical properties of soil closer to optimal, and also to control weeds, it is necessary to carry out a relatively large number of mechanical operations, often using herbicides to clean the fields.

To obtain a fine-grained soil structure in the seed location, it is not necessary to crush it intensively and thereby increase the energy intensity of the process. The desired structure can be obtained by combining the operation of crumbling soil and its fractional distribution along the depth of cultivation.

Results and discussion. In the field, the qualitative indices of the machine performance for optimizing the ploughed layer of soil were assessed by the soil structure, density, and moisture. An experimental plot of 1 hectare was ploughed in autumn into a depth of 25-27 cm and divided into two parts. One part of the plot (control) in the spring was tilled with the KPS-4 cultivator with tooth harrows into a depth of 10 cm, the second part was tilled with an experimental machine into the same depth. The physical and mechanical properties of soil during the experiments were determined in accordance with OST 70.2.15-73.

The moisture content of soil was determined by thermal drying in fivefold retaking. Soil samples weighing 0.03-0.04 *kg* were placed in aluminum cups, weighed and dried in a moisture-testing oven at a temperature of 105°C for eight hours. After drying, the soil samples were weighed again. The moisture content of soil was determined according to the formula:

$$W_a = \frac{m_в - m_c}{m_c} 100\% \qquad (1)$$

where $m_в$, $m_с$ – respectively, the mass of wet and dry soil, *kg*.

The hardness of soil was determined with the help of the VISHOM hardness tester in a fivefold retaking.

The soil density was determined in a threefold retaking by the cutting ring method according to N.A. Kochinsky.

To determine the structural-aggregate composition of soil, a method was used to sift it on sieves with round holes. A sample weighing not less than 2.5 *kg* (in triplicate retaking) was brought to an air-dry state and sieved through a sieve without wiping. The soil remaining on the sieves was weighed and the relative weight of each fraction was calculated according to the formula:

$$\Phi = \frac{m}{M} 100\%, \qquad (2)$$

where *m* – the fraction mass, *kg*;

M – mass of the sample received for analysis, *kg*.

The coefficient of soil structure was calculated according to the formula:

Table 1

Structural composition of black soil typical (April), number of units in, %

Aggregate dimensions, mm	Depth, 10^{-2} m					
	Control			Experiment		
	0-5	5-10	15-25	0-5	5-10	15-25
Dry sifting						
>10	45.01	43.40	46.0	11.4	26.9	47.2
10-7	8.31	10.27	10.4	5.2	9.5	10.6
7-5	7.45	6.77	7.9	4.4	7.0	8.1
5-3	9.93	9.36	9.6	7.0	8.0	10.5
3-2	9.15	8.52	8.1	11.7	11.3	8.4
2-1	12.90	15.28	11.9	34.6	2.0	9.0
1-0.5	1.50	1.36	1.4	3.4	2.7	1.4
0.5-0.25	3.34	2.94	2.7	11.6	10.9	2.6
<0.25	2.38	2.10	2.2	1.3	1.7	1.6
10-0.25	57.61	54.50	51.8	87.3	73.1	51.2
$K_{стр}$	1.27	1.20	1.08	3.41	2.72	1.05
Wet sifting						
7-5	0.58	0.56	0.13	0.30	0.66	0.08
5-3	1.08	1.53	0.23	0.05	1.11	0.14
3-2	1.10	1.01	0.56	0.08	1.10	0.40
2-1	3.27	2.94	2.62	0.77	3.58	2.66
1-0.5	16.08	13.12	12.28	7.13	7.75	14.90
0.5-0.25	40.85	39.48	44.60	44.73	14.25	43.95
>1	6.03	6.02	3.54	1.15	6.44	3.28
>0.25	62.96	58.62	60.41	53.06	58.43	62.12
$K_{стр}$	0.65	0.60	0.62	0.60	0.60	0.63

$$K_{cmp} = \frac{K_{10-0,25}}{K_{>10} + K_{<0,25}}, \quad (3)$$

where $K_{10-0.25}$ – percentage of agrotechnically valuable soil fractions in the sample;

$K_{>10}$, $K_{<0,25}$ – percentage of the content of soil fractions in the sample, respectively, less than 0.25 *mm* and more than 10 *mm*.

The physical and mechanical properties of soil are determined in two stages after the spring cultivation in conditions of a bare (black) fallow field: in April and in July (Tab. 1 and 2).

Table 2

Structural composition of black soil typical (July, dry sifting), number of units in, %

Aggregate dimensions, mm	Depth, 10^{-2} m					
	Control			Experiment		
	0-5	5-10	15-25	0-5	5-10	15-25
>10	5.6	28.0	34.8	7.1	24.8	30.3
10-7	4.2	8.3	10.6	3.3	7.2	9.5
7-5	4.1	8.2	8.7	4.1	7.6	10.3
5-3	6.8	11.5	11.7	6.4	9.2	14.3
3-2	11.1	12.3	10.9	10.1	10.8	13.2
2-1	36.4	20.5	15.5	37.6	22.5	14.6
1-0.5	3.8	1.9	1.5	3.1	2.3	1.6
0.5-0.25	12.3	5.3	3.4	11.7	7.3	3.9
<0.25	15.7	4.0	2.9	16.6	8.4	3.3
10-0.25	71.9	68.0	62.3	76.3	66.8	66.4
$K_{стр}$	2.55	2.14	1.73	3.26	2.02	2.42

It can be seen from Table 1 that after soil cultivation by the experimental machine, the amount of soil aggregates larger than 10 *mm* as compared with the control ones in layer 0-5 is 4 times lower and in layer 5-10 is almost 2 times lower. The number of agrotechnically valuable soil aggregates (10-0.25 *mm*) in the experimental version is greater by approximately 30% than in the control one. The structural coefficient of the cultivated soil layer (0-10 *cm*) by the experimental machine is approximately 2.5 times higher as compare with the control one.

Wet sifting of the soil showed that there is practically no difference in the coefficients of water resistance of soil clumps in both variants. In the structural-aggregate composition of soil, in two months after its cultivation, the differences between the experimental and control areas are smoothed out.

The difference in soil density over the layers at different times did not exceed 3-4% (Tab. 3).

Table 3

Density of soil composition, g/cm³

Depth, 10^{-2} m	April		July	
	Control	Experiment	Control	Experiment
0-5	1.06	1.05	1.10	1.11
5-10	1.14	1.15	1.19	1.16
15-25	1.19	1.18	1.12	1.19
30-40	1.18	1.12	1.13	1.13

Fig. 4 shows the quality of cultivating a section of the field by the experimental machine

Fig. 4. A section of the field processed by an experimental machine

Data on the dynamics of changes in soil moisture content over the layers are presented in Table 4. Almost in all soil layers with depth in the soil cultivation variant by the experimental machine as compared with the control variant, the moisture content of soil during two months after its spring cultivation was 1-2% higher;

Table 4

Soil moisture content in layers, %

Depth, 10^{-2} m	April		July	
	Control	Experiment	Control	Experiment
0-5	16.33	18.19	15.59	17.95
5-10	21.33	23.46	20.25	21.37
15-25	25.03	24.29	21.37	23.70
30-40	23.34	25.18	22.34	24.86

moreover, the difference in soil moisture persisted even in July.

To establish how the experimental machine affects the weed infestation of the fields, a bare (black) fallow field was tilled in mid-May. The results of using the experimental machine are shown in Fig. 5.

Fig. 5. The result of black fallow processing by an experimental machine

Weed plants, including root shoots, are thrown out to the surface of the field with an intact root system (Fig. 6), provided that self-seeding is not allowed the costs of introducing herbicides are thus eliminated.

Fig.6. Weed on the surface of the field with an intact root system

Conclusion. Field studies have shown that the ripping-and-separating machine provides a 1.7-fold increase in the coefficient of the soil structure, better accumulation and preservation of moisture, by 3-4% higher as compared to the control variant. Pre-sowing tillage with the use of the machine allows to skip pre-sowing harrowing and cultivation, as well as prepare the soil for sowing in one run. The considered machine for optimizing the agrophysical properties of the ploughed soil layer, as compared with traditional cultivators, allows to increase the structural ratio by about 2.5 times, to maintain the soil moisture content in summer by 1-2% higher than in the control variant, and significantly reduce the weed infestation of the cultivated soil layer.

REFERENCES

1. Pashchenko VF, Syromyatnikov Yu.N., Khramov N.S. Fizicheskaya sushchnost' protsessa vzaimodeystviya s pochvoy rabochego organa s gibkim elementom [The physical background of the interaction process of a working unit with a flexible element with soil] // *Sel'skoe khozyaystvo*. 2017. N3: 33-42. (In Russian)

2. Pashchenko V.F., Syromyatnikov Yu.N. Pochvoobrabatyvayushchaya pristavka k zernovoy seyalke v tekhnologiyakh "No till" [Soil-tillage attachment to a grain seed drill in "No till" technologies] // *Aekonomika: ekonomika i sel'skoe khozyaystvo*, 2018. N3: 27. (In Russian)

3. Melnik V.I. Evolyutsiya sistem zemledeliya – vzglyad v budushchee [Evolution of farming systems – a look into the future] // *Zemledelie*. 2015. N1. (In Russian)

4. Syromyatnikov Yu.N. Povyshenie effektivnosti tekhnologicheskogo protsessa dvizheniya pochvy po lemekhu pochvoobrabatyvayushchey rykhlitel'no-separiruyushchey mashiny [Increasing the efficiency of the soil motion technological process along the share of a soil cultivating ripping-and-separating machine] // *Sel'skoe khozyaystvo*. 2017. N1: 48-55. DOI: 10.7256 / 2453-8809.2017.1.22037. (In Russian)

5. Syromyatnikov Yu.N. Obosnovanie profilya lemekha s napravlyayushchimi diskami pochvoobrabatyvayushchey rykhlitel'no-separiruyushchey mashiny [Justification of a share profile with guide discs of a soil cultivating ripping-and-separating machine] // *Sel'skoe khozyaystvo*. 2017. N2: 18-29. DOI: 10.7256 / 2453-8809.2017.2.23150. (In Russian)

6. Pashchenko V.F., Kim V.V., Batulin AA.. Teoreticheskie issledovaniya tekhnologicheskogo protsessa pochvoobrabatyvayushchey mashiny [Theoretical studies of the technological process of a tillage machine] // *Inzheneriya prirodokoristuvannya*. 2015. N1: 79-83. (In Russian)

7. Kachinsky N.A. Struktura pochvy [Soil structure] / N.A. Kachinsky. Moscow: MGU, 1963: 100. (In Russian)

8. Krut V.M., PabatI.A. , Rashko Kh.Kh. Vlagosberegayushchie priemy obrabotki pochvy i ukhoda za chernym parom [Moisture-saving methods of soil cultivation and bare (black) fallow processing] // *Zemledelie*. 1987. N10: 40-42. (In Russian)

9. Kuznetsov N.G. Sokhranenie plodorodiya pochvy pri vozdeystvii na nee khodovykh sistem traktorov i rabochikh organov mashin [Preservation of soil fertility under the influence of running gears of tractors and machine working parts] // *Vestnik sel'skokhozyaystvennykh nauk*. 1978. N7: 115-118. (In Russian)

10. Nekrasov P.A. Rabota frezy i pluga [Operation of a rotary plow and a plow]. Moscow: 1931: 64. (In Russian)

11. Pabat I.A. Gruntozakhisna sistema zemlerobstva [Soil protection system in agriculture]. Kiev: Urozhay, 1992: 158. (In Ukranian)

12. Pigulevsky M.Kh. Puti i metody izucheniya fiziko-mekhanicheskikh svoystv pochvy v tselyakh pravil'nogo konstruktivnogo oformleniya i ratsional'noy ekspluatatsii sredstv mekhanizatsii pochvoobrabotki [Ways and methods of studying the physical and mechanical properties of soil

in order to properly design and rationally use the mechanization means of soil cultivation] // Fizika pochv v SSSR. Moscow: Selhozgiz, 1936: 209-233. (in Russian)

13. Pigulevsky M.Kh. Rezul'taty vozdeystviya na pochvu sokhi, pluga i frezy [Results of the effect on the soil of a wooden plow, a plow and a rotary plw] / M.Kh. Pigulevsky. Moscow: Sel'khozhiz, 1930: 46. (In Russian)

14. Medvedev V.V. Pochvenno-ekologicheskie usloviya vozdelyvaniya sel'skokhozyaystvennykh kul'tur [Soil-ecological conditions for cultivating agricultural crops] / V.V. Medvedev. Kiev: Urozhay, 1991: 173. (In Russian)

15. Bondarev A.G., Rusanov V.A. , Medvedev V.V. Zaklyuchenie [Conclusion] // Pereuplotnenie pakhotnykh pochv. Moscow: Nauka, 1987: 205-210. (In Russian)

16. Savel'ev Yu.A., Kukharev O.N., Laryushin N.P., Ishkin P.A., Dobrynin Yu.M. Snizhenie poter' pochvennoy vlagi na isparenie [Reducing soil moisture loss caused by evaporation]. *Sel'skokhozyaystvennye mashiny i tekhnologii*. 2018. Vol. 12; 1: 42-47. DOI 10.22314/2073-7599-2018-12-1-42-47 (In Russian)

17. Mazitov N.K., Lobachevsky Ya.P., Dmitriev S.Yu., Sakhapov R.L., Sharafiev L.Z., Rakhimov I.R. Upgraded technology and equipment for soil processing and sowing in extreme conditions // *Russian Agricultural Sciences*. 2015, Vol. 41; 1: 75-79. (In Russian)

The paper was submitted to the Editorial Office on 04.04.2018 The paper was accepted for publication on 03.06.2018

Conflict of interest. The author declares no conflict of interest.

CC BY

DOI 10.22314/2073-7599-2018-12-3-45-52

Tendencies and Prospects for the Development of Domestic Machinery for Sowing Grain Crops

Andrey Yu. Nesmiyan[1],
Dr. Sc. (Eng), Professor of Department;

Yulia S. Tsench[2],
Ph.D. (Ed), Leading Reseacher

[1]Azov-Chernomorsky Engineering Institute, Donskoy State Agrarian University, Zernograd, Rostov Region, Russian Federation;
[2]Federal Scientific Agroengineering Center VIM, Moscow, Russian Federation, e-mail: vimasp@mail.ru

Abstract. The design of domestic grain drills largely determines the quality of sowing and the effectiveness of technologies for cultivating farm grain and seed crops in general. (*Research purpose*) To consider the development stages of domestic industrial production of grain drills and, in the form of an analytical review, to present the main information a chronological order. (*Materials and Methods*) the authors have conducted an expert analysis of the results of domestic scientists' research on the effect of the surface distribution of seeds on the yield of grain crops and determined general trends in the development of sowing machines, which made it possible to implement various methods of sowing cereals. The authors have also identified the main trends and stages of industrial production of grain drills in the Soviet Union and the Russian Federation. (*Results and discussion*) The contribution of Russian and Soviet scientists to the improvement of grain drills and the issues of the optimization of structural and operational characteristics of sowing units have been analyzed in the paper. The authors have determined and examined the main directions of development of grain drill in the pre-perestroika period, as well as characterized the state of the domestic agricultural machinery industry at the present stage. (*Conclusions*) Basing on the results of the conducted research, the authors have found that the development of grain drill designs in the domestic agrarian market is influenced by various reasons and has several directions. Among the most obvious trends we can single out the following ones: the use of the best foreign samples as prototypes; a tendency to increase the area of plant nutrition; the use of operational experience and comparative test results; optimization of design and technological parameters of drills based on the results of targeted scientific research; the development of machines that ensure the rational utilization of the energy resources used; extending the functionality of sowing machines as a result of combining operations and carrying out sowing on stubble backgrounds.

Keywords: seed drills, seed-sowing units, coulters, seed grain tubes, cereals, row seeding, dispersion sowing, seeding-down, development of designs.

For citation: Nesmiyan A.Yu., Tsench Yu.S. Tendencies and prospects for the development of domestic machinery for sowing grain crops. *Sel'skokhozyaystvennyye mashiny i tekhnologii*. 2018. 13(3): 37-43. DOI 10.22314/2073-7599-2018-12-3-45-52. (In Russian)

The effectiveness of technologies for cultivating grain crops, which form the basis of agricultural production in most developed countries, largely depends on the agrotechnical indicators and the period of sowing. Therefore, the improvement of sowing technology, its constructive refinement, increasing operational and technological indicators has always been and still is an urgent task.

Research purpose is to consider the development stages of domestic industrial production of grain drills and, in the form of an analytical review, to present the main facts in a chronological order.

Materials and methods. For hundreds of years, the main method of sowing in Russia remained manual spreading. The situation changed little towards the beginning of Russia's capitalist development: individual, hand-crafted coulter drills were rare and expensive, so they were used only on large and well-off farms [1]. A more economical direction of seed mechanization was the use of seed spreaders (Fig. 1), which as compared to manual spreading allowed to increase productivity and the uniformity of seed distribution over the field surface and reduce their rate. At the end of the 19th century, the seed spreader of Grinevitsky was widely used and it was produced by several workshops [2]. Since 1900, a new Kiev plant of Filvert and Dedin started producing combined seed drills [3]. However,

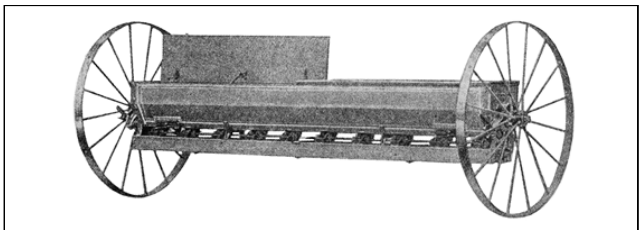

Fig. 1. A wide-track seed spreader

the unevenness of the depth of subsequent seeding significantly reduced the yields, so that their use, and, consequently, production, gradually ceased [4]. Further on, the remaining models were completely converted to fertilizer spreaders, although on some farms they were used as drills until the beginning of the Great Patriotic War.

The industrial production of coulter drills in our country and abroad began in the late 19th century. At that time, several plants were producing sowing machines in Russia, the largest of which was the Elisavetgrad plant (now Chervona Zirka, Kropivnitsky, Ukraine). The factory was founded in 1874 by British businessmen brothers Robert and Thomas Elvorti as a workshop for the repair of agricultural implements, which by the beginning of the 20th century had grown into a large enterprise for the production of horse-driven drills, threshers and oil mills. Light single-row 7-row drills with anchor coulters and a sling harness, a two-horse 11-row seeders with anchor coulters and 12-row seeders with double-disc coulters were in great demand [5].

A special place in the range of agricultural equipment produced at the enterprise was occupied by a wide-gauge seed spreader "Russia" (Fig. 1) with improved coulters and roller sowing machines, which was equipped with an improved device for plowing coulters into the soil. Thanks to its high technological properties, ensuring uniformity and high quality of seeding, the seeder was repeatedly awarded at major trade shows and invariably aroused great interest among both domestic and foreign producers and suppliers of agricultural implements and technical equipment. It was produced until 1927 [6].

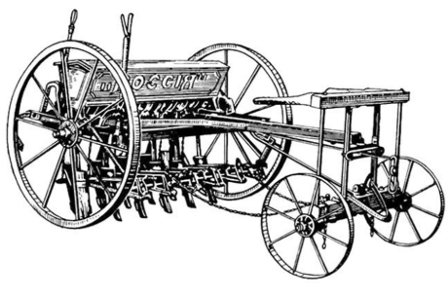

Fig. 2. 11-row coulter grain drill «Russia» (1895)

The drills were also produced by Kharkov Russian-German partnership "M. Gelferikh-Sade "(a serial model of the “Krestyanka” brand), the Bryansk locomotive plant (a model of the "Vernaya" brand), etc. At the First All-Russian Exhibition of seeds and seeding machines, in 1908, seeders from the above-mentioned manufacturers of agricultural machinery and other domestic enterprises were in high demand [7].

Even though Russia entered the phase of capitalist development later than other countries, its production of simple agricultural machines came the third in Europe and the fifth in the world by 1913. The amount of produced units was 59 thousand pcs. a year. Basically, these were horse-driven seed drills, providing an inter-row spacing with an interval of 125-150 mm [7-9].

However, by that time many well-known scientists and production workers (P.A. Kostychev, N.S. Sokolov, V.V. Wiener, and others) noted that the existing arrangement of coulters was not scientifically grounded and was caused, rather, by the need to reduce their possibility of being clogged with stubble residues (mortmass). At high seeding rates, this row spacing results in a decrease in plant productivity due to excessive thickening in rows, and the deviation of the plant nutrition shape from optimum. As early as in 1881, P.A. Kostychev noted that, according to the results of field experiments, the method of sowing with a row spacing of about 75 mm, at the same seeding rates is much more effective than a regular drill placement. Studies on different crops carried out at the Shatilovskaya Experimental Station (1902-1903 and 1910-1911), the Rostov Experimental Station (1913-1917) and later, ensured a significant increase in yield to 20-26% [10].

In the absence of special narrow-row drills, V.V. Wiener (Shatilovskaya Experimental Station) at the end of the XIX century proposed cross sowing as an effective replacement of narrow-drill placement. Numerous studies and production experience have confirmed its effectiveness, but also revealed significant shortcomings: significant energy and labor costs, the influence of the second run of the coulters on the depth of seeding of the first-run seeds and a prolonged sowing period [10].

During the First World War and the Civil War, most of the scientific research was practically stopped, and the production of seed drills stopped completely. Only by 1925 it was again possible to establish a stable level of their output, although it was 1.6 times lower than the pre-war level (35.8 thousand units/year) [7-9].

Machines of that time were distinguished by a wide variety of designs. On the territory of the country there were more than 110 different models of seed drills, which made it difficult to rationally operate them and restrained the establishment of large-scale industrial production. Thanks to the work of the special commission under the leadership of V.P. Goryachkin, the number of perspective seed drill models was reduced to 7. A considerable amount of data, on the basis of which the commission evaluated the drill models and gave an expert opinion, was obtained on the basis of an experimental model developed by V.P. Goryachkin and consisting of a fixed seed drill with a belt conveyor with a sticky surface underneath it [10].

In 1929, the production of tractor drills started at the Krasnaya Zvezda plant in Kirovograd (now Kropivnitsky, Ukraine). In 1931, the plant was completely transferred to the production of 11- and 13-row horse-driven and tractor drills. The second large enterprise specializing in the production of seed drills was the Kherson plant. Later large-scale production of seed drills was also deployed at the Rostov plant of agricultural machines named after I.V. Stalin (now JSC KZ "Rostselmash") [7].

It was planned to establish the production of a 22-row drill by the “Krasnaya Zvezda” plant in Rostov-on-Don. However, the commission of the People's Commissariat of the USSR made a choice in favor of a 24-row seeder with two-disc coulters, a prototype for which was the technical innovation of that time - a grain drill of direct sowing McCormick produced by American agricultural machinery manufacturers in 1927. This decision was due to the results of comparative tests of the models of domestic seed drills and European companies Praner, Melicher and Sakk, as well as American Moline and Massey Harris, which were conducted in Rostov. With a row spacing of 6 inches (152 mm), the McCormic’s direct seeding drill proved to be the most efficient. It was reliable and easy to manufacture and operate, and also featured high performance [11].

The seed drill SD-24 (Fig. 3) of the Rostselmash plant, modeled on the McCormic model, had cast boxes of seeding mechanisms with lower seeding and adjustable bottoms, individual emptying and double disc coulters. Later this model became the basis for the development of various types of seed drills: grain-cotton drill SZH-6, grain-grass drill NWT-47, linseed drill C-47, grain-combined drill SK-24, grain-vegetable drill SOD-24 and others [7, 11].

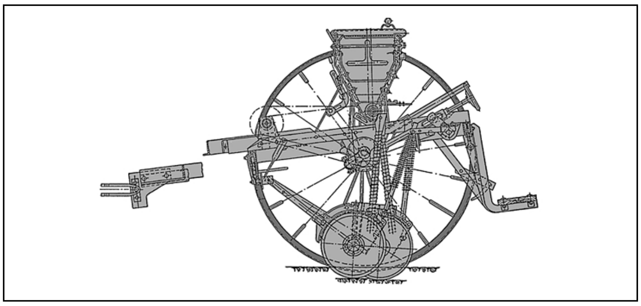

Fig. 3. The grain drill SD-24

Another family of unified seeders was developed on the basis of the seed drill SD-10. It included the grain-and-vegetable drill SOD-10, grain coulter drill SA-12, linen drill SL-17, grain-grass NWT-19, beetroot-grain combined drill SK-10, etc. [7].

Specialists of the “Krasnaya Zvezda” plant also adopted the McCormic drill as a prototype. However, taking into account the experience of designing sowing machines, they did not completely copy it, but made a number of significant changes: they translated the documentation into a metric system, changed individual parameters to those already tested by domestic practice, and made maximum use of specialized units of their own production. As a result, at the end of 1929 the plant produced a T-I series seed drill. By the spring sowing campaign of the following year, the plant produced 750 units of seed drills and sent them for testing in full-scale conditions in almost all soil-climatic zones of the country [11].

Gradually the seed drill was improved, designers developed transient models T-II and T-III on its basis, and by 1931 a model T-IV was prepared for serial production. According to the year plan the plant was to produce 58 thousand seed drills, of which 40 thousand units were of T-IV series [11].

Soon the designers were tasked to develop a seed drill for tractors of SKhTZ, with an engine power of about 30 hp and the S-60 - 60 *hp*. The designed seed drill T-V with a box holding up to 500 kg of grain was too heavy, and its serial production was not approved. Instead, a seed drill T-VII (Fig. 4) was adopted for production, which could be aggregated with the Fordzon-Putilovets tractor (20 hp), and in a double hitch it was possible to use more powerful tractors [11].

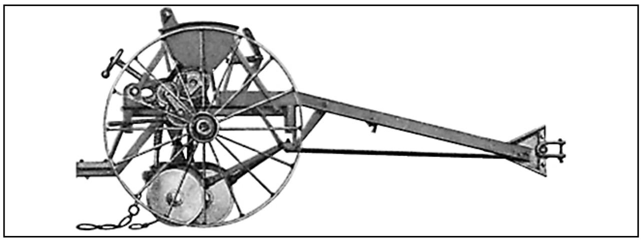

Fig. 4. Grain seed drill T-VII

This seed drill produced by the "Krasnaya Zvezda" plant had stamped sowing units with bottom and top seeding, 24 double-disc coulters with seed feed behind the axis and a seed hopper with a capacity of 240 *kg*. The total width of the seed drill was 3.6 *m*. The seed drill was produced before 1939 [11].

In those years, the research conducted by P.A. Nekrasov in the Moscow region, the specialists of Belarusian Agricultural Institute, Kiev Institute of Scientific Methods of Sowing, the Odessa Regional Experimental Station and other scientists made it possible to address the question of the irrational distribution of seeds on the field surface during drill seeding [10]. In this connection, on the initiative of the engineer and agronomist D.Y. Kamyshchenko, a SKT-52 narrow-row seed drill with two-row coulters (Fig. 5) was developed and in early 1937 the “Krasnaya Zvezda” plant mastered its production [11].

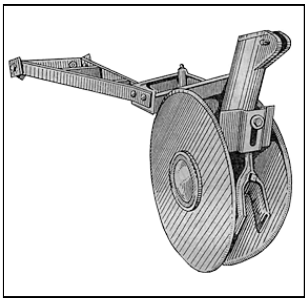

Fig. 5. Two-disc double-row coulter

Practical experience

has shown that the working process of a narrow-row seed drill is characterized by increased energy intensity, the depth of seeding is more uneven, the travel speed of the unit is lower (accordingly, the sowing time is increased) [10]. The use of narrow-row seeders was not completely canceled, but the level of their production and use was significantly reduced.

Results and discussion. By 1939, the country had 607.8 thousand horse-driven and 109.6 thousand tractor-driven seed drills. Moreover, the production of tractor-driven seed drills increased, while that of the horse-driven ones was reduced and completely stopped in the first post-war years [7, 9].

Brief technical characteristics of some seed drills produced in the pre-war years in the USSR [10] are given in Table 1.

Table 1

Technical characteristics of seed drills (the 1930-40s)

Seed drill make	Sowing width, mm	Row spacing, mm	Mass, kg	Traction effort	Sowing units	Coulters
SD-10A	1500	150	350	2, 3 horses	roller feed	double-disc
SA-12	1500	125	350	2 horses	roller feed	anchor-type
SZT-19	1350-1500	75-150	450	2, 3 horses	cast iron roller feed	keel-shaped
SK-10	1500	150	534	4000-5000 N (tractor)	cast iron roller feed	anchor mixed-type
СД-24 SD-24	3600	150	995	4000-5000 N (tractor)	cast iron roller feed	double-disc
T-VII	3600	150	1000	4000-5000 N (tractor)	iron roller feed	double-disc
SZKh-6B	3600-4200	150-654	1245	4000-4500 N (tractor)	special and roller feed	keel-shaped with slides
SK-24	3600	150	1018	4000-5000 N (tractor)	cast iron roller feed	anchor mixed-type
SZT-47	3450-3600	75	1250	4500-5500 N (tractor)	cast iron roller feed	double-disc or keel-shaped
SA-48B	3600	78	995	4500-5500 N (tractor)	steel narrow-typed	double-disc with dividers

At that time, the researchers paid close attention to the continuous (uncontrolled) method of sowing, which has the advantages of both seed spreading, narrow-row, and cross-ways methods, but partially without their shortcomings. Studies conducted in 1949-1957 in the conditions of the Kuban machine testing station, Kherson and Odessa Agricultural Institutes and other places confirmed the economic effect almost equal to the effect obtained with narrow-row sowing. However, it was noted that special paw coulters (Gurnitsky coulters) cannot be effectively applied to soils that are weedy, lumpy and wet (more than 20% moisture), as the energy intensity of the process increases substantially [10].

Since the 1930s, the improvement of grain seed drills was achieved by copying the best foreign samples and practically justified upgrades, and using a deep experimentally confirmed theoretical base. At this time, to the research results of V.P. Goryachkin, B.A. Kril' and others were supplemented by the data of many authors, which made it possible to substantially optimize the design of grain seed drills.

A.N. Karpenko, M.N. Letoshnev and A.N. Semenov, conducted an extensive analysis of the regularity of the volume supply of seeds by the sowing mechanism roller [10, 12]:

$$V_o = l_p\,(\beta z f + \pi d C_{пр}) \qquad (1)$$

where V_o – the amount of seeds fed by the sowing device to the receiving hopper per one revolution of the roller, m^3; l_p – working length of the roller, m; β – filling factor of the grooves; z – the number of grooves; f – cross-sectional area of grooves, *pcs*, m^2; d – external diameter of the sowing roller, m; $C_{пр}$ – reduced thickness of the active layer of seeds, m.

The reduced thickness of the active layer of seeds ($C_{пр}$) depends not only on their physicomechanical properties, but also on many other factors, including the length of the working part of the roller [10]. It was experimentally established that, for example, for wheat this dependence is described by a polynomial:

$$C_{пр} = 0{,}0065\, l_p^2 - 0{,}281\, l_p + 6{,}2075. \qquad (2)$$

Basing on the study results of the seed feeding process, we have proposed the dependences of the roller grooves, which make it possible to determine the working volume of the grooves, for example, according to M.N. Letoshnev's cross-sectional area of the roller grooves [12]:

$$f = \frac{r^2}{2}(\pi - \alpha - \sin(\pi - \alpha)) +$$

$$+\frac{d^2}{8}(\alpha' - \sin\alpha') + \frac{b^2 - 4r^2(\cos 0.5\alpha)^2}{4\,\mathrm{tg}\,0.5\alpha}, \quad (3)$$

where r, α, α', b – geometric parameters of the roller

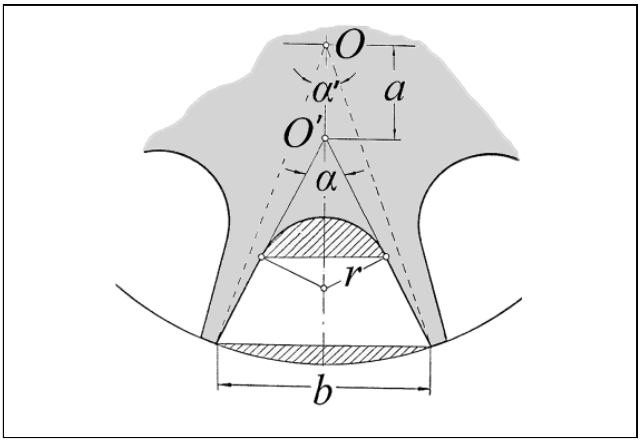

Fig. 6. Scheme for calculating the cross-sectional area of a groove of the seeding unit roller

(Fig. 6).

The performed calculations made it possible to determine the rational parameters of the sowing rollers and seed boxes (the unit casings), and optimize their mutual arrangement.

The influence of the design and parameters of a seed grain tube on seed dispersion has been studied as well, rational parameters of coulter groups, transmission line, and the hopper have been determined, and great attention having been paid to the uniformity of the seeding depth, the rational pressure of the various coulter types on the soil, and the optimization of the sowing units as a whole, with taking into account their kinematic and dynamic characteristics [13, 14].

In the 1950s, on the basis of research and development works, a new family of tractor seeders with improved performance indicators was designed. The basic model of the new family is the unified 24-row grain drill SU-24 (Fig. 7). Its modifications were SUK-24 seeders, narrow-row SUB-48 designs of the Stalin Prize laureate V.D. Bogatchev, SZT-47, SZTK-47, and others (Tab. 2),

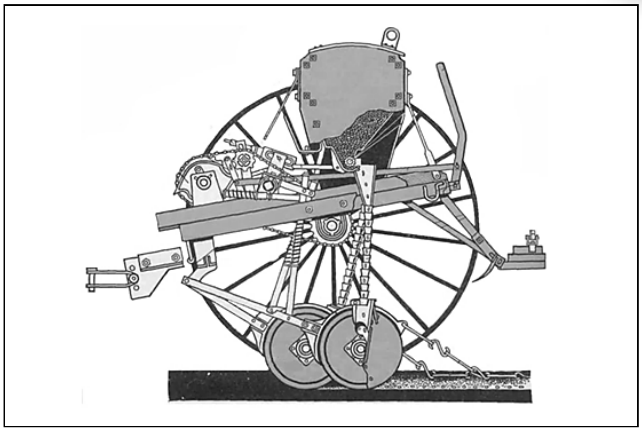

Fig. 7. The grain drill SU-24

equipped with disk and tine point coulters [7, 9].

In general, by the early 1950s, the prewar level of seed drill production was surpassed by more than 4 times. Thanks to this, mechanization of grain sowing

Table 3

Increase in the level of mechanization in sowing grain crops

Years	1933	1940	1950	1955	1965
Level of mechanization, %	7.0	56.0	74.0	94.0	100

significantly increased (Tab. 3) [7-9].

The introduction after 1958 of hinged seed drills SZN-10, SZN-16, SZN-24, SZNK-24. SLN-20, SLM-32, SLN-48 proved to be insufficiently effective for a number of reasons, the main of which were: the impossibility of a simultaneous introduction of fertilizer and seeds and the presence of a hitch in wide-coverage units. The first had to be done to decrease the seed drill weight, the second circumstance nullified the saving of metal during its manufacture [7, 8].

For the areas prone to wind erosion of soil, special machines were developed: a seed drill LDS-4A (the Krasnoyarsk combine plant), a grain seed drill SZP-24 (Krasnaya Zvezda) and a stubble drill SZS-9 (Syzran combine plant) [7, 8, 15].

The development in a short time of machines differing in design and purpose required the implementation of works on the universalization and unification of seed drills on the basis of the latest achievements of science and advanced experience. As a result, there appeared

Table 2

Technical characteristics of some seeders (the 1950s)

Seed drill make	Sowing width, mm	Row spacing, mm	Mass, kg	Performance, ha/h	Traction effort, N	Sowing units	Coulters
SUK-24	3600	150	1014	1.62-2.68	5500	cast iron roller feed	double-disk
SUB-48	3550	68-80	1100	1.62	up to 6000	cast iron roller feed	double-disk with dividers
SZTK-47	3600	Grain 150 Total 75	1330	up to 2.6	up to 6000	roller feed	double-disk and keel-shaped

a family of combined seeders with a high degree of unification with pneumatic wheels, a hydraulic coulter lift, and an improved design of all working bodies. The basic model of this family is the S3-3,6 seeder (Fig. 8),

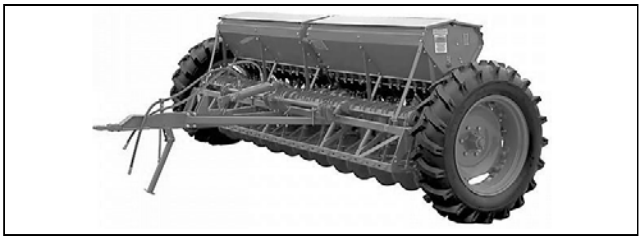

Fig. 8. Grain drill C3-3,6

launched in the production in 1971.

In the no-hitch version, it was aggregated with tractors of 50-82 *hp*.

Its modifications: SZU-3,6 – a narrow-row drill, SZP-3,6 – a press drill, SZA-3,6 – an anchor drill, SZO-3,6 – a single-disk drill SZL-3,6 – a flax drill, SZT-3,6 – a grain- (grassland) drill, SRN-3,6 – a rice drill, SZS-2,1 – a stubble drill, LDS-6 – a seed drill-stubble cleaner; SZG-2,4 – a mountain drill.

The Krasnaya Zvezda, Belinskkselmash and Sibselmash plants mastered the production of modernized grain drills equipped with seven types of working bodies, NWT-3,6A and SZP-3,6A for sowing cereals and other crops in various ways using intensive technologies [7, 9].

On the basis of the S3-3,6A seed drill, a combined seed drill SZK-3,6 was designed to apply the full rate of mineral fertilizers simultaneously with the sowing of grain crops. When a device for the application of a full rate of mineral fertilizers was disconnected, it was transformed into an ordinary C3-3.6A, and with a connected device for sowing grass seeds in NWT-3,6A [7, 9].

For seeders C3-3, 6A, feeding containers (seed boxes) were installed common to all the sowing machines and accommodating the amount of seeds sufficient for 1.5-2 hours of operation.

The volume of the feeding container can be determined by the formula:

$$V = \frac{LBQ}{10^4 \gamma \eta_e}.$$

L – length of the furrow from the filling, *m*;
B – width of machine grip (or row width), *m*;
Q – seeding rate, kg/m^3;
γ – density of seeds, kg/m^3;
η_e – utilization of tank capacity, equal to 0,85-0,9,

In the pre-perestroika years in the early 1980s, grain seed drills of new generations were developed in our country: wide-spread pneumatic stubble drills SZS-14 and SZS-8; wide-spread seed drills-cultivators SZS-12 and SZS-6; no-hitch grain seed -fertilizer drills SZP-8, SZP-12 and SZP-16 capable of being converted into ordinary ones: a combined seed drill SZK-3,3; a modernized rice seed drill SRN-3,6A; a modernized family of seed drills S3-3,6, providing convenient maintenance and increasing the reliability and quality of sowing. The sowing machines were operated with tractors with an engine power from 80 to 240 *hp*. [7-9].

Currently, along with ordinary monoblock seed drills, similar to the SZ and its modifications, sowing machines of centralized sowing and sowing complexes using pneumatic seed transportation are increasingly distributed on the domestic market. In general, in the absence of a planned economy, without a pronounced specialization of farm machinery building enterprises, the variety of manufactured machines has grown substantially. Taking into account the fact that many farms are still using Soviet equipment and various foreign sowing machines, it can be asserted that not a hundred different brands of grain seed drills are present on the market, as it used to be at the dawn of Soviet industrial development, but many hundreds.

Conclusion

Today, the following implements are widely applied in planting technology: systems of process automation and precision farming; multi-row placement of coulters and pneumatic conveying of seeds, which allows to obtain any reasonable row spacing; the use of powerful tractors (up to 530 *hp*) provides seedless sowing on untreated stubble soil, the use of single wide-spread soil cultivating and sowing complexes. But whatever a seed drill of the future might be, its design will be based on the knowledge obtained by many generations of engineers and agronomists living long before us.

In general, the analysis has shown that the development of the design of grain seed drills on the domestic agrarian market is influenced by various factors and it is multi-directional.

The most obvious trends include: the use of the best foreign samples as prototypes; a tendency to increase the area of plant nutrition; the use of operational experience and comparative test results; optimization of design and technological parameters of drills based on the results of targeted scientific research; the development of machines that ensure the rational utilization of the energy resources used; extending the functionality of sowing machines as a result of combining operations and carrying out sowing on stubble backgrounds.

REFERENCES

1. Khalanskiy V.M. Ekskursiya za plugom [Excursion following the plow]. M.: Kolos. 1974: 207. (In Russian)

2. Seyalka v razbros Grinevitskogo [The dispersion seeder of Grinevitsky]. SPb.: Tipografiya i litografiya K. Sorvanova. 1873: 5. (In Russian)

3. Kapitonov Ye.N. Istoriya sel'skokhozyaystvennogo mashinostroyeniya Rossii: monografiya [The history of agricultural machinery in Russia: Monograph]. Tambov: Izdatel'stvo TGTU. 2010: 60. (In Russian)

4. Harris P.S. Farm machinery and equipment. New York and London: McGraw-Hill Book Company. 1937: 460. (In English)

5. Izmaylov A.Yu., Buklagin D.S., Mishurov N.P., Gol'tyapin V.YA., Kolchina L.M., Solov'yeva N.F., Shilova Ye.P. Sel'skokhozyaystvennaya tekhnika: Katalog Ministerstva sel'skogo khozyaystva Rossiyskoy Federatsii po inzhenerno-tekhnicheskomu obespecheniyu agropromyshlen-nogo kompleksa [Agricultural machinery: Catalogue of the Ministry of Agriculture of the Russian Federation for engineering and technical support of the farm industry]. 1. Tekhnika dlya rasteniyevodstva. M.: 2005. 288. (In Russian)

6. Artobolevskiy I.I., Blagonravov A.A. Ocherki istorii tekhniki v Rossii (1861-1917). M.: Nauka, 1975: 397. (In Russian)

7. Savenko V.A. Ryadovyye seyalki [Common drills]. Zernograd: ACHGAA, 2006: 154. (in Russian)

8. Minin P.I. Razvitiye otechestvennogo sel'skokhozyaystvennogo mashi-nostroyeniya [The development of domestic agricultural machine-building] // *Sel'khozmashina*. 1957. N10: 4-8. (In Russian)

9. Sysolin P.V. Etapy razvitiya otechestvennykh zernovykh seyalok [Stages of development of domestic grain seed drills] // *Mekhanizatsiya i elektrifikatsiya sotsialisticheskogo sel'skogo khozyaystv*a, 1979. N12: 16-17. (In Russian)

10. Semenov A.N. Zernovyye seyalki [Grain seed drills]. Moskva, Kiyev: Yuzhnoye otdeleniye Mashgiz. 1959: 318. (In Russian)

11. Yevseyev L. Seyalka [The drill] // *Tekhnika molodezhi*. 1977. N6: 52-56. (In Russian)

12. Letoshnev M.N. Sel'skokhozyaystvennyye mashiny [Agricultural machinery]. Leningrad, Moskva: Sel'khozgiz, 1955: 764. (In Russian)

13. Veys Yu.A. Pochvoobrabatyvayushchiye i posevnyye mashiny travo-pol'noy sistemy zemledeliya [Soil-cultivating and sowing machines of grassland farming system]. Minsk: Redaktsiya sel'skokhozyaystvennoy literatury. 1952: 207. (In Russian)

14. Svirshchevskiy B.S. Ekspluatatsiya mashinno-traktornogo parka [Operation of the machine and tractor fleet]. M.: Sel'khozgis. 1958: 467. (In Russian)

The paper was submitted to the Editorial Office on 20.03.2018 **The paper was accepted for publication on 05.06.2018**

Conflict of interest. The authors declare no conflict of interest.