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TECHNOLOGICAL AND TECHNICAL IMPROVEMENT OF CROP CULTIVATION PROCESSES

Gennady Maslov ^{1*}, Nikolai Rinas ¹, Elena Yudina ¹, Nikolai Malashikhin ¹

¹ Department of Operation Machine and Tractor Park, Kuban State Agrarian University named after I.T. Trubilin, RUSSIA.

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ABSTRACT

This article presents the technological and technical principles for improving the technology of cultivating field crops by optimizing them. New technological principles significantly improve technology by combining operations on tillage, sowing, fertilizing, harvesting, and technical - reducing the list of machines, the use of universal energy tools, multifunctional units that qualitatively implement the technology. The novelty of the research consists in the rational acquisition of machine units in accordance with the inventions of the authors. This will help to obtain improved results of technical and economic efficiency, such as labor productivity, energy intensity of processes and the cost of investing in the mechanization of technological processes.

Disciplinary: Crop Science, Agricultural Machinery and Technology.

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1. INTRODUCTION

The technologies of cultivating field crops and agricultural machinery for their implementation determine not only the crop, but also the technical and economic efficiency of the grown products [1], labor productivity and competitiveness. Unfortunately, the applied technology in the form of single-operation machines does not allow using the potentialities of even high technologies for cultivating field crops, achieving the highest labor productivity and minimizing production costs [2, 3]. However, even from modern serial technology it is possible to obtain high efficiency using the technological and technical principles that we offer to improve field crop cultivation processes based on scientifically based farming systems and manning machine assemblies based on our inventions [4, 5, 6, 7, 8]. Thus, the goal of our article is to provide increased labor productivity and lower costs when cultivating crops by streamlining the technology system and serial machines, taking into account our inventions.

2. METHOD

In this work, we used the method of analysis and synthesis of research results, computer programs for optimizing the parameters and operating modes of machine units [1, 3, 9], field experience technique of B. A. Dospikhov [9] and GOST R 53053-2008 on the economic evaluation of machines and technologies.

Small plot experiments on aggregates were laid down in triplicate according to the procedure [9] with a systematic arrangement of plots. In addition to the control, measurements of the working speed of the soil, the structurally aggregate composition of the soil, the depth of cultivation with the determination of its uniformity, as well as the determination of the traction resistance of the working bodies with the help of dynamometry were measured for each experiment. The results of checking the uniformity of the depth of soil cultivation by various working bodies on the harrowing of winter wheat crops are given in Table 1.

Also, according to the specified method [9], a multi-functional unit for sowing wheat was studied with the simultaneous introduction of the main, sowing fertilizer and rolling [7] and a multi-functional harvesting unit with the simultaneous pressing of straw [2, 4]. In comparison with the original domestic combine with a rotating deck TORUM-740, the quality indicators of grain threshed with heavy threshing and separating devices were compared.

The technological principles for improving the processes of cultivating field crops (Figure 1) are formed in four blocks (a – d): a - technology optimization; b - resource, energy saving; c - soil improvement; d - innovative technology. All these principles are based on serial technology with its completion in multifunctional units (MFU), capable of fundamentally improving the technology: eliminating heavy equipment from machine complexes, streamlining the list and sequence of operations, nomenclature list of machines, combining several technological operations in one pass of the unit field, reduce crop losses, costs and improve the quality of work.

Consider the structure and content of each of the four blocks of directions. In the first of them: technology optimization strictly stipulates the rotation of crops in crop rotation and selects the best technology option taking into account the predecessor. It provides continuous execution of all planned work in precisely defined terms and with careful observance of agrotechnical requirements at each technological operation with a minimum number of tillages. Of course, such optimization is expected to significantly increase labor productivity, reduce costs, cost of production and increase its competitiveness. The optimized technology includes a set of high-performance multifunctional equipment, the use of highly effective herbicides in a complex to protect plants from weeds, the use of a set of highly productive and reliably ripening varieties of different maturity, the use of full doses of organic and mineral fertilizers, and strict adherence to technological discipline. All of the above will make it possible to achieve 2–2.5 times savings in fuel and lubricants, labor costs - up to three times, and ensure yield growth by 30 percent. In addition, the number of machine brands will be reduced, for example, for grain production from 20–30 to 5–6 items, while capital investments in mechanization are reduced by a factor of 1.5–2.

When optimizing, for example, the technology of harvesting cereal crops, they must take into account the full range of operations of the post-harvest complex: on what area is stubble peeling

carried out, on which sowing of intermediate crops or chiseling, what and how much fertilizer is applied. Optimization criterion - minimum cash costs or total energy costs. When optimizing grain harvesting, they plan to use multifunctional units that collect grain at the same time and perform a number of post-harvest complex operations. The composition of the MFU can be formed on the basis of.

The second block (b) of resource and energy conservation presents directions for improving grain production, including the problems of combining technological operations, improving technologies based on the new universal mobile energy facility UES-450 (PO Gomselmash), using ultra- and low-volume spraying with an effective plant protection system saving energy resources by optimizing them for the planned crop and optimizing the selection of the best option for grain harvesting technology taking into account the emerging environmental bottom climatic conditions.

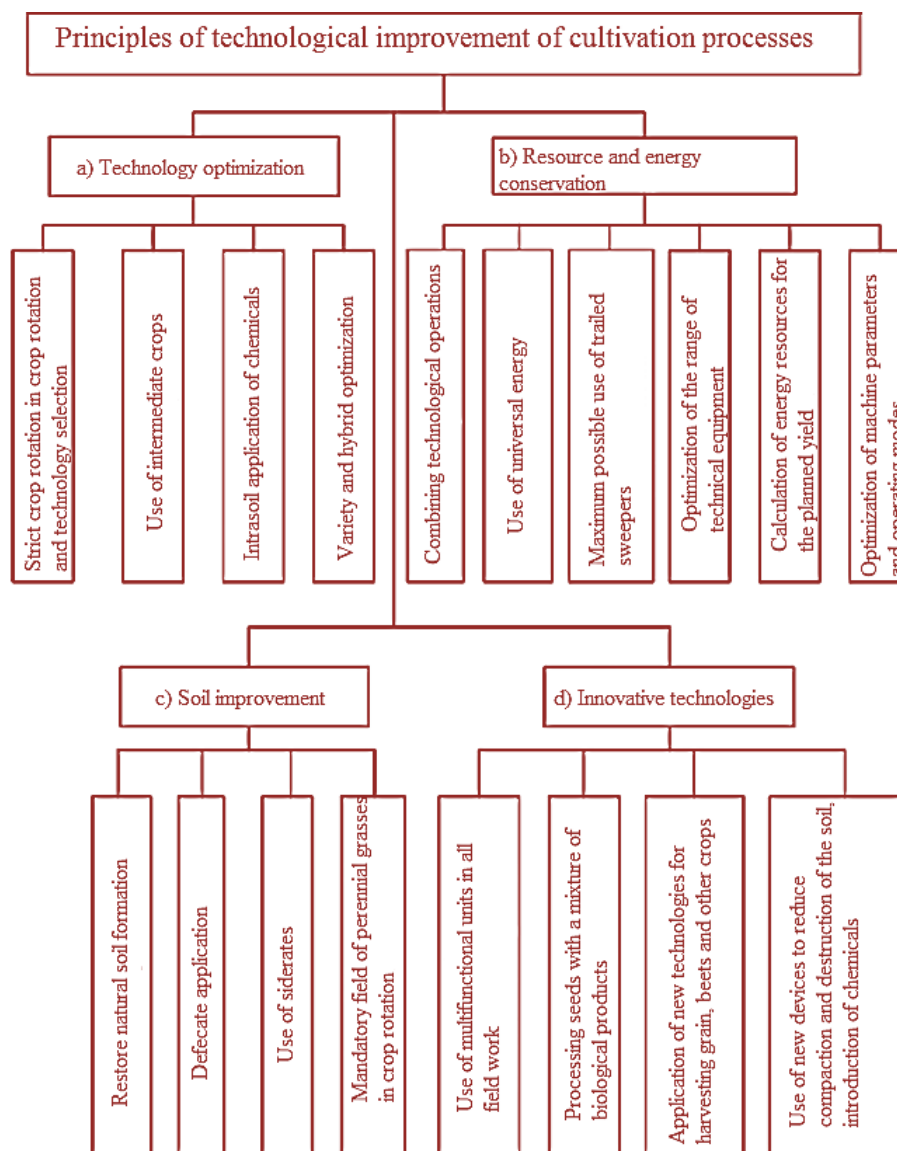


Figure 1: Principles of technological improvement of crop cultivation processes

3. RESULT AND DISCUSSION

The combination of technological operations in one machine-tractor units (MTU) is very widely used in both domestic and foreign technologies. This is especially noticeable on machines for tillage, sowing, fertilizing [4]. Even when harvesting cereal crops, it is proposed to combine harvesting with other works: stubble cultivation, sowing of intermediate crops, pressing straw.

Combination of operations on the new powerful mobile energy facility U-450 (Gomselmash Production Association) is especially effective. This universal power vehicle of a 5 t traction class can create a fundamentally new direction in scientific research and technology [7]. We performed a study to determine the effectiveness of a system of machines for mechanizing crop production in a typical economy of our region with an energy facility of U-450 and a system of machines based on serial equipment without U-450 (Table 1).

Table 1: Performance indicators of a system of machines for plant growing with energy U-450

	Indicators	Actual fleet of a typical farm	Settlement Park	
			without U-450	with U-450
1	The number of conventional reference tractors (150 l. From.), Pcs.	12.74	10.94	10.08
2	Number of physical tractors	14	12	9
3	Arable land load, ha:			
	on a physical tractor	184.3	215.0	286.7
	on conditional tractor	202.5	235.8	255.9

As follows from the results obtained, the use of the U-450 power tool with a set of machines fundamentally improves technology and ensures high efficiency: the range of technical equipment, the number of conventional reference tractors (Table 1) are significantly reduced from 12.74 to 10.8 pcs., Number of physical tractors - from 12 to 9, or by 25%, the optimal annual load of a conventional tractor increases from 202.5 ha to 255.9, which means that the cost of the work performed will decrease and the efficiency of technologies will increase.

Improving technology is achieved by combining technological operations, saving soil moisture and releasing the tractor.

The third block of technological improvement (Figure 1) includes mainly agricultural areas (restoration of natural soil formation, introduction of defecate, use of crop residues, strict observance of crop rotation, where a field for perennial grasses is mandatory).

A very significant and important technological direction of increasing the production of cereals and other crops in modern conditions is the improvement of the soil from various mushrooms and pathogens, which should increase the crop yield and give a high economic effect without the use of large doses of mineral fertilizers and chemicals. Some research teams are already finding ways to restore soil fertility through natural soil formation processes through the introduction of microbiological preparations that enhance the intensity of biological processes in the soil, support and restore these processes, bind, for example, air nitrogen, and provide plants with the necessary amount of nitrogen compounds, multiplying the crop . A proven drug for soil improvement is Geostim (LLC Biotehagro, Russia, Krasnodar Territory, Timashevsk). The technology of its application gives the best effect in complex processing: pre-sowing treatment of seeds of agricultural crops + treatment of

vegetative plants + post-harvest treatment of plant residues. Thanks to this technology, infections are suppressed in the soil, and agronomically valuable organisms and their metabolic products are decomposed and accumulated. To increase productivity, seeds are treated with the same preparation with a mixture of chemical preparations, mineral composts and biological products, due to which the plant is protected from seedling to vegetative maturity. Further, throughout the entire growing season, Geostim, settling on the surface of the root system of plants, provides free access to mineral nutrition elements, performs protective functions, releases biologically active substances, stimulates plant growth and development. And, finally, post-harvest stubble cultivation (spraying) immediately before the first or second disking, or before cultivation using a sprayer with large-droplet sprays using complex microbial starter cultures, the crop residues are effectively decomposed, infections are suppressed in the soil, and its healing takes place (density decreases, accumulate agronomically valuable organisms, etc.).

There are two drawbacks to the technologically unsolved problems in this useful innovation. Firstly, it is necessary to fulfill the requirements for a minimum time gap between spraying and tillage, and the second requirement is to provide a small drop spray of biological products on vegetating plants. The first of them is solved with the help of our multifunctional unit [8], which can be equipped with a sprayer, and the second - with the use of ejection-slot nozzles [9].

Consider the principles of technical improvement of technologies for sowing crops (Figure 2), which solve the problem of industry efficiency. As you can see, this is, first of all, a radical renewal of the fleet of machines and machine technologies that reduce the need for equipment, labor, fuel and lubricants and at times increase labor productivity.

The principles of technological technological improvement are proposed: effective multifunctional units (MFU) for mechanization of crop production, ensuring the production of competitive agricultural products; more advanced designs of machines and working bodies that improve the quality of mechanized work; issues of updating the fleet of vehicles, improving the efficiency of their use; complexity of work; continuity and flow of work; environmental safety of products. A high level of integrated work execution is based on combining several technological operations carried out in a single MFU pass, which radically improve the basic technology options. Obviously, a significant advantage of the proposed technology compared to the use of serial single-operation machines. The combination of several technological operations in one pass MFU is guaranteed to provide agrotechnical, environmental, energy and economic efficiency. Figure 2 presents the principles of technical improvement of crop cultivation processes.

In total, the technical principles of technology improvement (Figure 2) include 18 items included in four blocks (I – IV, Figure 2) I - optimization of the fleet; II - organization of work performed; III - improving the quality of work; IV - environmental safety. In block I, the main directions are the optimization of the composition of machine-tractor units (MTU), which should ensure the complexity of the work (II. 4) using multifunctional units (MFU) I. 2 with a minimum range of technical equipment (paragraph I. 3).

In the second block - the organization of the performance of work required threading II. 6 and

rhythm II. 7 processes and maintaining constant availability of machines II. 9 (Figure 2).

The third block - improving the quality of work is provided by optimizing the timing of their implementation (III. 12), reducing crop losses (III. 13) during harvesting, new working bodies of machines (III. 11), inextricably performing operations on time (III. 10).

The last IV block (Figure 2) - environmental safety provides for the preservation of soil fertility (IV. 14), reducing the number of passes of cars across the field and reducing soil spray by heavy equipment, reducing environmental pollution (IV. 18) and crop production (IV. 15), the widespread use of precision farming elements (IV. 16) and mechanization of tillage (IV. 17), where NOU TiL is possible [10].

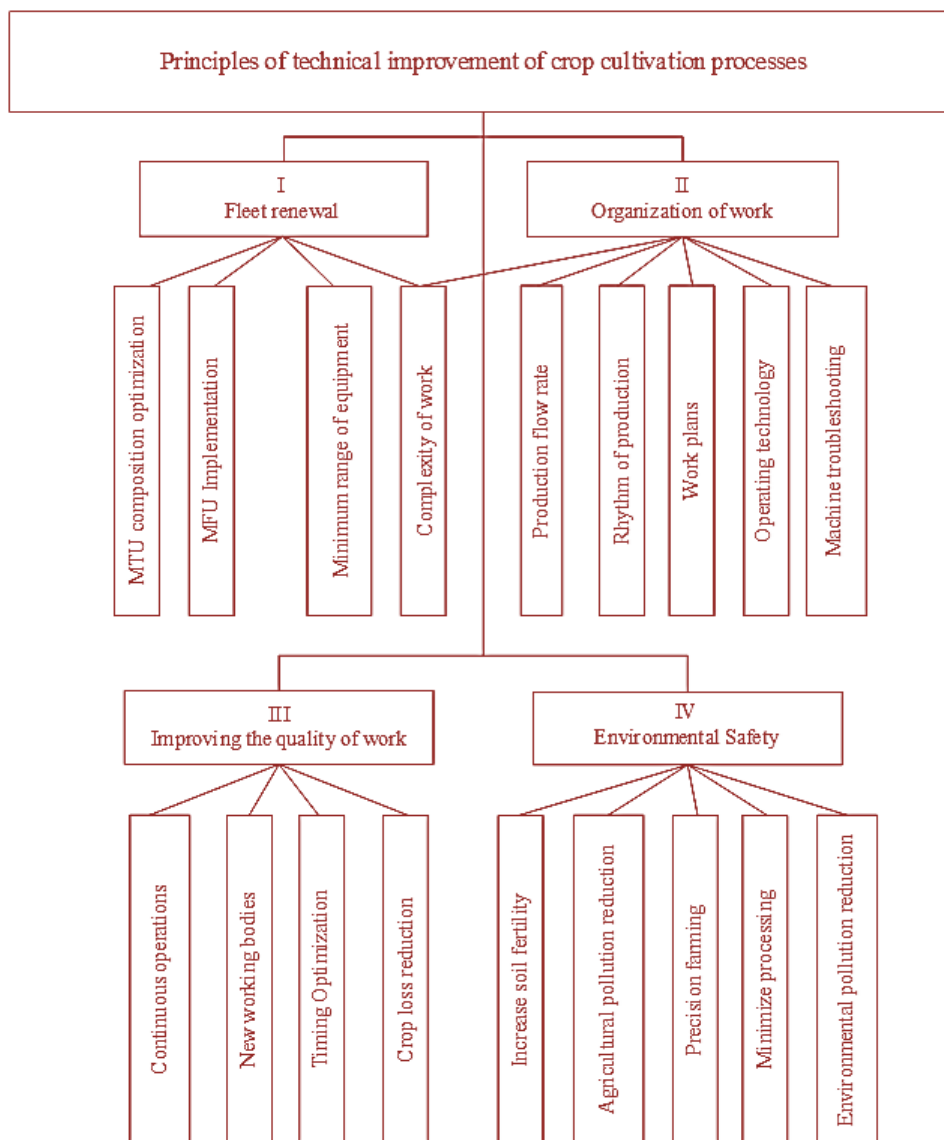
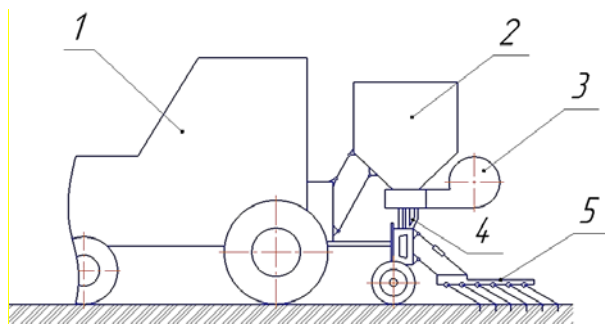


Figure 2: Principles of technical improvement of crop cultivation processes.

Our experimental samples of multifunctional machine units for harrowing the soil with simultaneous top dressing of crops are presented in Figure 3.



a) general view of the experimental unit with a spring harrow: 1-tractor; 2 - fertilizer hopper; 3 - fan; 4 - dispenser; 5 - harrow



b) general view of the unit for harrowing crops with a rotary hoe with simultaneous top dressing

Figure 3: Experimental samples of multifunctional units for harrowing crops with simultaneous feeding

When studying an aggregate with a rotary harrow (Figure 3b), we studied the uniformity of the depth of tillage (Table 3) in comparison with other harrowing machines: the ZBP-0.6 tooth harrow and the Klen-1.5 grain seeder for radical top dressing of winter crops.

From Table 3 it can be seen that, according to the experimental variants, the error of the sample average did not exceed 4.7%, the smallest depth of processing was at the seed drill ZBP-0.6, which amounted to 17.1 mm, then the passive arrangement of the discs of the rotary harrow was 27.5 mm, then the openers of the Klen-1.5 grain seeder are 32.6 and the discs of the rotary harrow with an active arrangement are 45.9 mm. Moreover, the unevenness of the processing depth, according to the coefficient of variation V, has a good and satisfactory value (11.2 - 21.1), except for the sowing harrow.

Table 2: Uniformity of the depth of tillage when harrowing crops options *

Experience Options	Mathematical expectation, M_{av} , mm	$\pm \sigma$, mm	V, %	P, %
1. Rotary hoe with active tooth positioning	45.9	5.13	11.2	1.6
2. Rotary hoe with passive tooth arrangement	27.5	4.6	16.7	2.4
3. Tooth sowing harrow ZBP-0,6	17.1	5.7	33.3	4.7
4. Grain seeder "Klen-1,5"	32.6	6.9	21.1	3.0

* σ – standard deviation; V – coefficient of variation; P – relative error of the mean.

Thus, according to the data of Table 2, the proposed multifunctional unit with a rotary hoe with an active tooth position provides a high-quality uniform depth of soil cultivation and incorporation of mineral fertilizers.

The method of modeling determined the optimal parameters and operating modes of the proposed multifunctional aggregates (MA) for harrowing with top dressing with a spring harrow and with a rotary hoe (Table 3).

Due to its high performance, a multifunctional unit with a spring harrow is more preferable (Table 4) compared to a rotary hoe MA. However, on heavy merged soils, a rotational hoe provides a more even depth of tillage and better quality of crumbling.

According to the results of our research, a multifunctional sowing unit for sowing wheat with simultaneous application of the main, starting fertilizer and rational rolling of the crops with a spiral-helical roller was also effective (Figure 4).

Table 3: Optimal parameters and operation mode of MA

Name of parameters	MA with spring harrow	MA with a rotary hoe
Tractor engine power kW	145.8	59.0
The carrying value of the tractor, thousand rubles	5640.7	1800.0
Width of capture of the unit, m	26	6.7
Fertilizer hopper capacity, m ³	1.0	1.0
Working speed, km / h	12	12
Soil resistivity coefficient	0.4	1.0
Productivity, ha / h	25	3.6
Utilization factor shift time	0.8	0.79
Cycle time during operation, h	0.54	-
The number of cycles per shift, pcs	12	-
Optimum headland, km	1.5	1.5
Specific operating costs for MA work, rub / ha	183.1	1700
Specific reduced costs, rub / ha	247.8	876.0
Specific capital investments, rub / ha	430.9	228.0

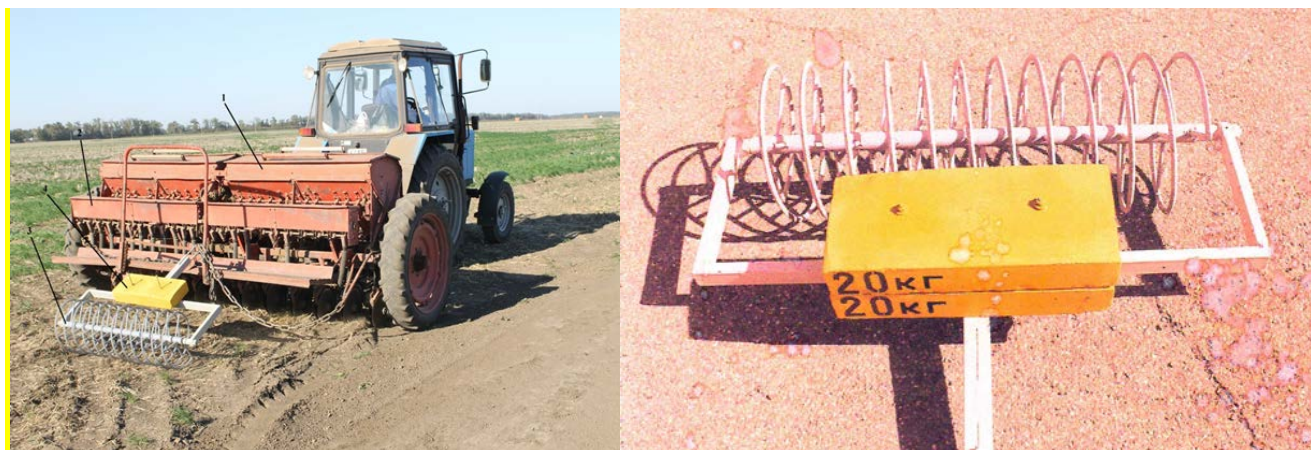


Figure 4: Multipurpose (a) sowing unit and (b) spiral screw roller with ballast weight

It was experimentally established that the unit provides high-quality sowing of winter wheat with a norm of 200 kg/ha, introduction of a starting dose of (phosphorus) fertilizer (50 kg/ha in physical mass), basic fertilizer N30P30K30 (363 kg/ha in physical mass) and rolling crops in a spiral screw roller. Compared with the control, an increase in grain yield of 1.73 kg/ha was obtained with the smallest significant difference ($HCP_{0.05} = 1.5$ kg/ha).

The packer roller creates a loose soil layer with destroyed capillaries above the packer layer to eliminate soil moisture losses; removal of crop residues and weeds absorbing nitrogen for fiber decomposition from the seed bed with spirals of the roller.

KKSh-6A ring-spur rollers used in basic technologies do not provide such conditions for wheat

seeds. They leave not rolled up to 60-70% of the sown area, do not create a loose layer above the rolled layer that prevents the evaporation of moisture.

The proposed unit can be used for sowing all cereal crops, thereby eliminating the negative violations of agricultural requirements in the basic technology.

Our studies confirm the positive effect of multifunctional aggregates on winter wheat grain yield (Table 4). A yield increase is provided by a unit based on a rotational hoe with simultaneous top dressing of winter wheat crops in addition to reducing operating costs by 6.9 percent, metal consumption by 19.4 percent and energy consumption by 4.2.

According to the results of the experiment, it was concluded that the combination of harrowing operations of winter wheat crops with simultaneous fertilizing with nitrogen fertilizers provided a significant increase in grain yield of 1.77 c/ha compared to control plots with the same dose of fertilizers, but without harrowing. In this case, the smallest significant difference (NDS) in the experiment was 0.71 kg/ha with a confidence level of 0.05. (1 c/ha = 100 kg/ha).

Table 4: Effect of multifunctional aggregates on winter wheat grain yield

Experience Options	Grain yield, kg/ha in replicates			Yield increase, c/ha	HCP _{0,05}
	1	2	3		
MA for top dressing					
Control	59.3	59.1	58.6	-	-
Experience	61.2	60.8	60.3	1.77	0.71
MA with the introduction of basic fertilizer and rolling					
Control	72.4	72.0	72.8	-	-
Experience	74.0	73.8	74.03	1.78	1.5

In the experiment with the use of a multifunctional unit for sowing winter wheat with the simultaneous introduction of the main, starting fertilizer and rolling, an increase in grain yield of 1.8 c/ha was also obtained in relation to the control plots of the experiment with the separate application of the main, starting fertilizer and rolling the sowing with ring-spur rollers ZKKSh-6 with HCP_{0,05} = 1.5 c/ha. The yield increase in the second experiment is explained by the better distribution of the main fertilizer in the soil to a given depth of 16-18 cm compared to their distribution over the entire plowed layer by the plow after application by spreading machines. In addition, rolling the crops with a spiral-helical roller is better than ZKKSh-6 ring-spur rollers, when up to 70 percent of the area remains unpacked to the desired density [4].

In the second block - the organization of the performance of work required threading II. 5 and rhythm II. 6 processes and maintenance of constant readiness of machines II. 9 [2] (Figure 2).

The third block - improving the quality of work is provided by optimizing the timing of their implementation (III. 12), reducing crop losses (III. 13) during harvesting, new working bodies of machines (III. 11), inextricably performing operations on time (III. 10).

The optimal duration of wheat harvesting is justified using the cost and loss function: the cost of harvesting grain and straw with the proposed multifunctional harvesting unit (Figure 5a) and losses - the cost of crop losses (Figure 5b) associated with a possible excess of the harvesting time over the optimum.

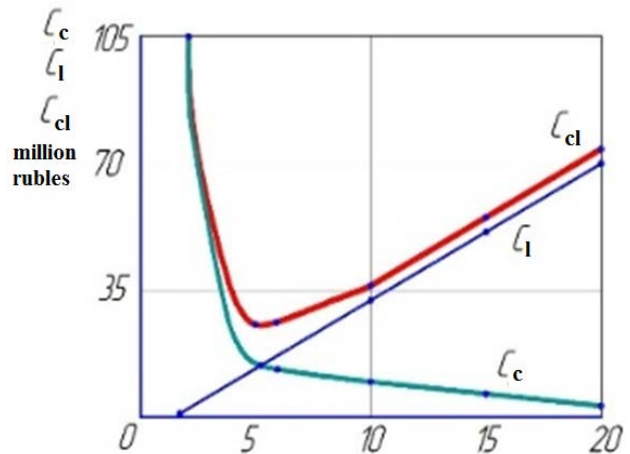


Figure 5: General view of the multifunctional harvesting unit with the simultaneous pressing of straw (a) and a graph of the dependence of the cost function C_c and loss C_1 (b)

For the conditions of the Krasnodar Territory, when modeling the cost and loss function, the optimal harvesting time of 5 days was obtained at the minimum value of the cost and loss function C_{cl} ($C_{cl} = 5931$ rubles) at the cost of costs ($C_c = 3162$ rubles) and losses ($C_1 = 2768$ rubles).

As an energy source for a multifunctional harvesting unit (Fig. 5a), the domestic TORUM-740 combine harvester with a rotary threshing and separating device (MCU) has been substantiated, which has great advantages compared to the powerful MCU (Figure 6).

As follows from the analysis of Figure 6, rotary LSG has an advantage in all quality indicators of threshing: grain crushing compares to 10 times by 10%, micro-damage by 10-12%, total grain losses decreased from 2.5% on the LSU to 1.8% - on the rotary.

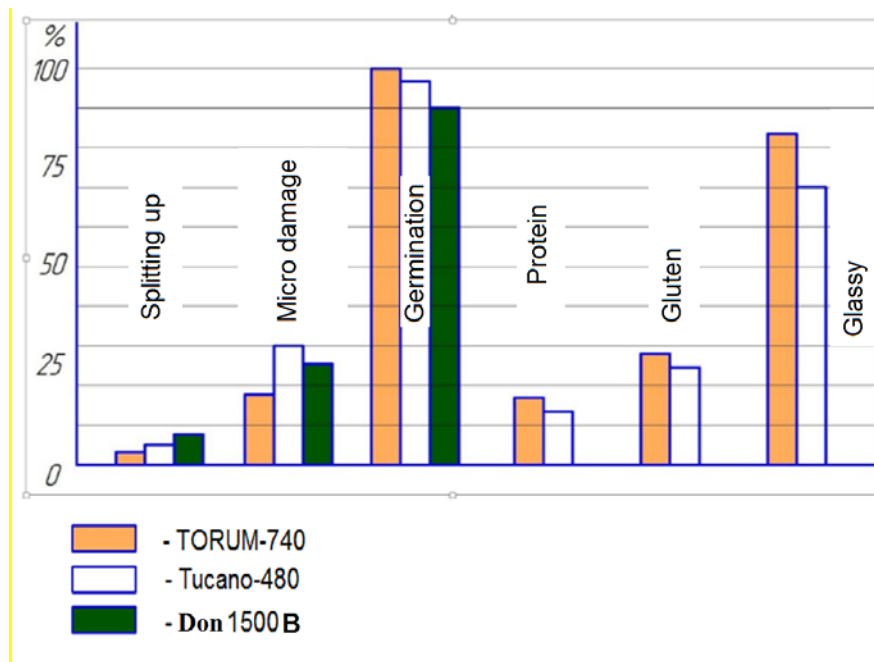


Figure 6: Diagram of quality indicators of threshing wheat of Olkhon variety with different designs of LSG

The quality of the threshing for crushing grain affected the germination and its technological properties (Table 5).

Table 5: Qualitative indicators of winter wheat grain of Olkhon variety when threshing with various MSU

Indicator	Value for MSU	
	rotary	beating
Grain crushing,%	0,38	4,5
Microdamage to grain,%	17,5	24,0
Loss of crop spray%	0,04	0,45
The protein content in the grain,%	17,0	14,0
Gluten content,%	27,0	23,5
Grain Class	2	3
Seed germination energy,%	55	49
Seed germination,%	96	91

Judging by the data in Table 5, severe trauma to the grain by the beating LSGs and an increase in yield losses in comparison with rotary combines are confirmed. In addition, grain quality is significantly improved when threshing with rotary MSU: the protein content in the strong Olkhon variety increased by 3 percent, the gluten content by 3.5. The energy of seed germination also increased from 49 to 55% and laboratory germination from 91 to 96%. After harvest ripening and cleaning, the grain class after rotary MSU increased from the third to the second, which did not happen after a bitter MSU due to a violation of the secondary synthesis in the caryopsis due to increased injury to the machines.

The last IV block (Figure 2) - environmental safety provides for the preservation of soil fertility (IV. 14), reducing the number of passes of cars across the field and reducing soil spray by heavy equipment, reducing environmental pollution (IV. 18) and crop production (IV. 15)), the widespread use of precision farming elements (IV. 16) and mechanization of tillage (IV. 17), where Splitting up No-Till is possible [10].

Thus, on the basis of the study, it is possible to form the following areas of technical improvement of crop production technology (Figure 2):

- updating equipment with a minimum range of technical equipment based on the optimization of the composition of the ICC;
- compliance with the continuity, flow and complexity of the production processes based on the use of MFU, combining several technological operations in one pass;
- technical update is inextricably linked with the organization of the efficient use of machines based on operating technologies and equipment service;
- improving the quality of mechanized work by improving the design of the working bodies of machines;
- observance of environmental safety of technical means to increase soil fertility, reduce pollution of agricultural products, minimize cultivation and precision farming.

The application of all the listed principles of technical improvement (Figure 2) using the proposed MFUs in production with completing them according to our inventions [4–8] and others.

All of the listed MFUs provide comprehensive field work, improved quality, productivity, lower costs and environmental pollution.

4. CONCLUSION

Thus, the work proposes technological and technical improvement of the processes of cultivating field crops by optimizing them, saving resources, adhering to the farming system, using multifunctional machine aggregates according to the inventions of the authors of the article, which contribute to the introduction of new agricultural methods that preserve and enhance soil fertility and ensure environmental protection. In the technical improvement of crop cultivation processes, universal energy facilities of the U-450 type (Republic of Belarus) provide high efficiency, which reduce the need for tractors by 25 percent compared to the actual fleet without U-450 and by the same amount improve the annual loading of tractors, reducing operating costs. The proposed technological and technical principles will help to organize production more efficiently and obtain competitive crop production.

5. AVAILABILITY OF DATA AND MATERIAL

Information can be made available by contacting the corresponding author.

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Professor Dr. Gennady Maslov is Professor, Department of Operation Machine and Tractor Park, Kuban State Agrarian University named after I.T. Trubilin. He holds a Doctor of Technical Sciences.



Nikolai Rinas is an Associate Professor, Department of Operation Machine and Tractor Park, Kuban State Agrarian University named after I.T. Trubilin. He is a Candidate of Technical Sciences



Elena Yudina is an Associate Professor, Department of Operation Machine and Tractor Park, Kuban State Agrarian University named after I.T. Trubilin. She is a Candidate of Technical Sciences



Nikolai Malashikhin is a Researcher, Department of Operation Machine and Tractor Park, Kuban State Agrarian University named after I.T. Trubilin.
