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Rational System Of Multifunctional Aggregates For Mechanization Of Plant Growing.

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ABSTRACT

This article presents a rationale for the system and presents a constructive technological scheme for multifunctional aggregates in place of single-operation machines for tillage, sowing, mineral fertilization, harvesting. The dependence of the mass of a multifunctional arable aggregate on its capture width is obtained. A block diagram of the algorithm for optimizing the parameters and operating conditions of the seeding unit is presented with simultaneous introduction of the main and initial fertilizer. The efficiency of the proposed multifunctional aggregates is given.

Keywords: multifunctional aggregates, efficiency, optimization, energy consumption, objective function, algorithm.

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INTRODUCTION

The main fundamental influence on the current state and development of agricultural machinery for the integrated mechanization of crop production is the problems of competitiveness of its products through energy conservation and environmental safety [1, p.1615; 2, p. 2071]. Constantly complicated economic, energy and environmental situation, on the one hand, requires obtaining high, stable harvests of field crops, high labor productivity, and, on the other hand, preserving and multiplying the fertility of the soil, saving energy resources.

In connection with the transition to a market economy and competition perspective technologies of cultivation of agricultural crops should be revised based on the strict respect of the zonal farming systems and the use of the latest technology. It is well known that due to the technique [3, p.1919] it is possible to significantly increase productivity and reduce costs. The main means of solving this problem, in our opinion, is the replacement of plant growing all single-machine multifunctional units (MFU). Under MFU, we mean a set of heterogeneous working machines as part of a single machine unit (MU) for performing a complex of agricultural works in one pass of the unit along the field: for example, tillage and fertilization, seeding with simultaneous application of the sowing and main fertilizer, fertilizing the crops with simultaneous loosening of the soil with rotary hoes, harvesting of grain by combines with simultaneous loosening of soil or sowing of intermediate crops, or pressing of straw, etc. [1, 5, 6].

MATERIALS AND METHODS

The main research method for justifying MFU is mathematical modeling in order to obtain their optimal parameters and operating modes. The target function of the motherboard and the block diagram of the algorithm for optimizing the MFU parameters for stubble cultivation of the soil with simultaneous application of mineral fertilizers was published by us earlier [3, p.1919]. In order to optimize the parameters of arable MFU with simultaneous application of mineral fertilizers, additional crumbling and soil leveling (Fig. 1), we developed a mathematical model with the objective function *E*, the minimum specific costs of total energy for performing the technological process by arable (MFU). The target function of the mathematical model includes: direct energy costs, determined by the amount of fuel consumed E_t on the operation of the unit, the expenditure of energy of living labor E_g, energy consumption for the tractor E_{tr} and agricultural machinery E_m (1):

$$E = \left(E_t + E_g + E_{tr} + E_m\right) \to \min, \quad (1)$$

where *E* – unit costs of total energy, MJ / ha;

E_t, E_g, E_{tr}, E_m – specific consumption of energy, respectively, consumable fuel, live labor, tractor and agricultural machinery, MJ / ha.

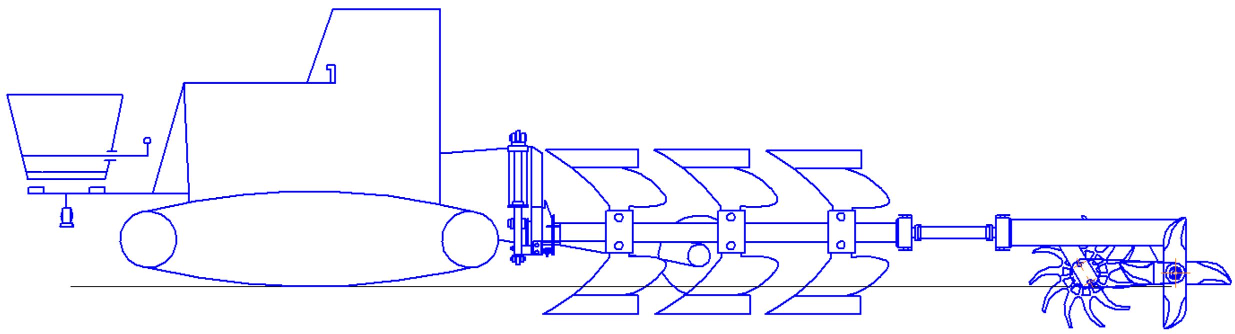


Figure 1: MPA for soil crumbling and leveling

In turn, the direct specific energy consumption is determined by the known formula [7, p.23]:

$$E_T = \frac{G_t}{W_h}\eta_t, \qquad \text{MJ / ha} \tag{2}$$

where G_t – specific fuel consumption of the engine during MFU operation, kg / h;
W_h – rate of MFU production per 1 hour of shifting time, per hour;
η_t – energy equivalent of diesel fuel, MJ / kg.
Living energy costs of living labor E_g [7, p.9]:

$$E_g = \frac{n_h \alpha_g}{W_h}, \tag{3}$$

where n_h - number of people serving MFU, people;
α_g - energy equivalent of living labor costs, MJ / h.

The energy costs for the operation of the tractor E_{tr} were determined by the formula (4) [7, p.10]:

$$E_{tr} = \frac{M_{tr}\alpha_{tr}}{100}\left(\frac{a_t}{T_{nt}} + \frac{a_{tk} + a_{tt}}{T_{zt}}\right), \tag{4}$$

where M_{tr} – tractor weight, kg;
a_t, a_{tt}, a_{tk} - deductions for renovation, major and current repairs of the tractor,%;
T_{nt}, T_{zt} - normative and zone annual tractor loadings, h;
α_{tr} - energy equivalent (energy costs per unit of mass production) of the tractor, MJ / kg.
Similarly, the energy consumption of farm machines E_m (formula 1) is determined.

Approximation method yielded the dependence of the mass of the arable MFU on the width of the recapture plow (Fig. 2).

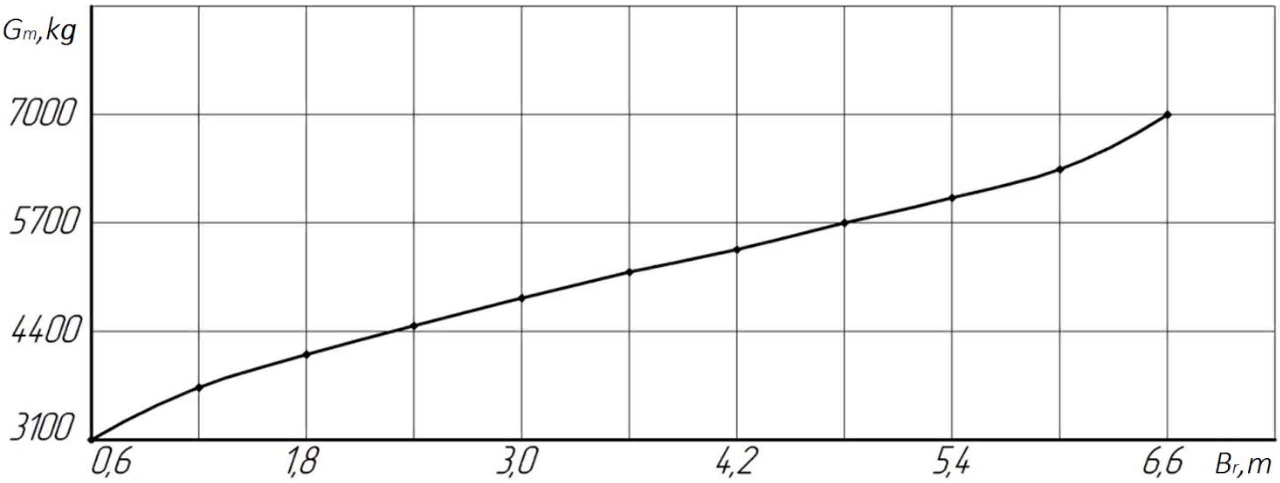


Figure 2: Dependence of the mass of MPA on the width of the plow B_r

$$G_{MPA} = 100/\left(-2{,}9\cdot 10^{-6} e^{B_r} - 6{,}394\cdot 10^{-3}\ln B_r + 0{,}0285\right), \tag{5}$$

where G_{MPA} - mass of multifunctional arable unit (MPA), kg;
B_r - working width of the turntable, m.

The adequacy of the obtained dependence is confirmed by the Cochran test: its tabular value G_t = 0,79 greater than the estimated G_r = 0,31.

When calculating the productivity of each MFU for 1 hour of shifting time (formula 2), it was necessary to determine the coefficient τ of using the shift working time. For clarity, we give a procedure for determining the coefficient τ in the example of MFU for harrowing crops with simultaneous top dressing [5].

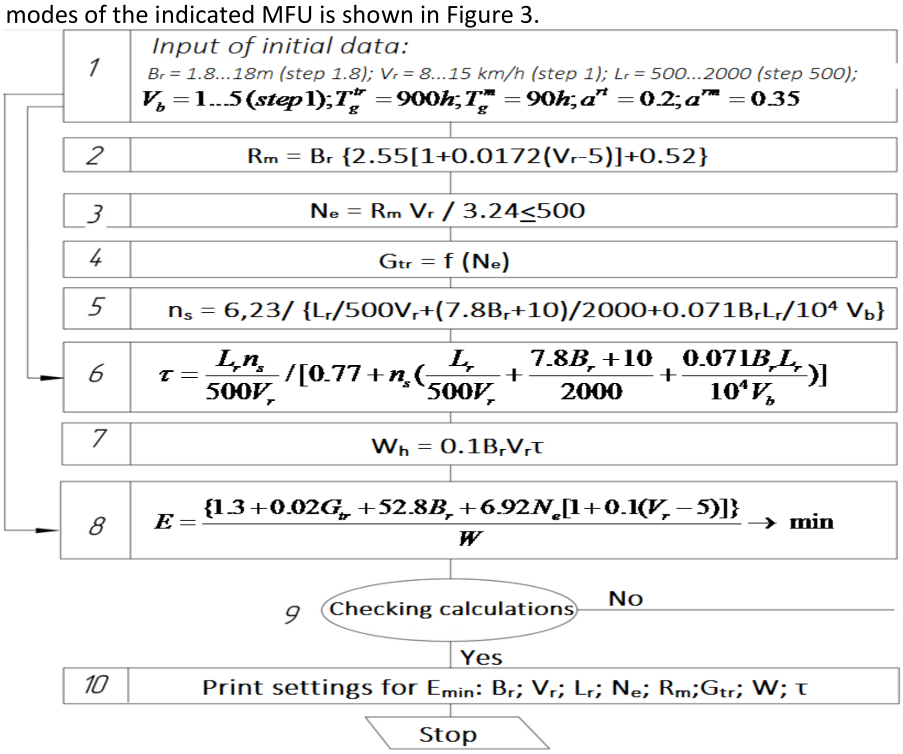
The coefficient of time use for the change of τ is determined by formula (6):

$$\tau = \frac{T_r}{T_{sm}} = \frac{t_{rs} n_s}{T_{sm}^d} = \frac{12,46 L_r}{7000 V_r \left(\frac{0,016 B_r L_r}{9900 V_b} + \frac{L_r}{500 V_r} + \frac{12 B_r + 12,4}{5000} \right)}, \qquad (6)$$

where T_r - basic (clean) operating time MFU per shift, h;
T_{sm} - normative changeable operating time MFU, h;
t_{rs} - working time of one cycle (this is the time taken to complete the two working and two idle passes through the field), h;
n_s - number of cycles per shift;
T_{sm}^d - actual duration of the shift, h
L_r - working length of a rut, m;
V_b - capacity hopper for fertilizers, m^3;
V_r - working speed, km / h.

The components of formula (6) n_s, t_{rs} , T_{sm}^d are determined by our method [8, p.86-87]. The theoretical dependences of the coefficient τ for MFU on the working speed V_r of motion, the length of the run L_r, and the capture width of the rotary hoe 6m are shown in Fig. 5 (a, c).

Optimization of MFU for sowing grain crops with simultaneous application of basic fertilizer, seeding and soil leveling with a screw roller is also performed according to the objective function - minimum of total energy costs for the process being performed. A block diagram of the algorithm for optimizing the parameters and operating modes of the indicated MFU is shown in Figure 3.



B_r - working width, m; V_r - working speed, km / h; N_e - engine power, kW; V_b - capacity of the hopper for fertilizers, m^3; L_r - working length of a rut, m; T_g^{tr} - annual tractor load, h; T_g^m - annual loading of agricultural

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machinery, h; a_{rt} - calculation of depreciation, repair and maintenance of the tractor in fractions of a unit; a_{rm} - also agricultural machinery; R_m – traction resistance MFU, kN; τ - coefficient of working time use shift.

Figure 3: Block diagram of the algorithm for optimizing the parameters and operating modes of the MFU for sowing grain grains and applying fertilizers

The method of justifying MFU for harvesting grain crops with simultaneous straw pressing is presented in our work [9, p.37], and the general view of the aggregate in Figure 4 (d).

RESULTS AND DISCUSSION

All the MFU system proposed by us is presented in Figure 4. Their effectiveness in comparison with single-operation machines is obvious, and they really will contribute to increasing the competitiveness of field crop production.

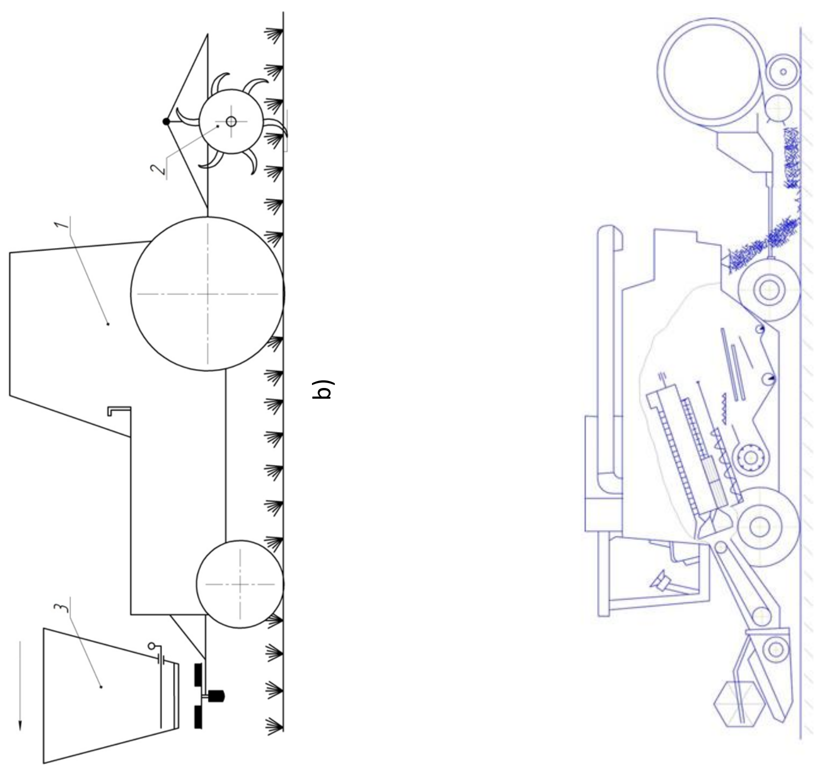
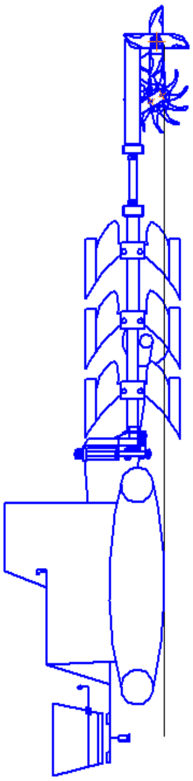
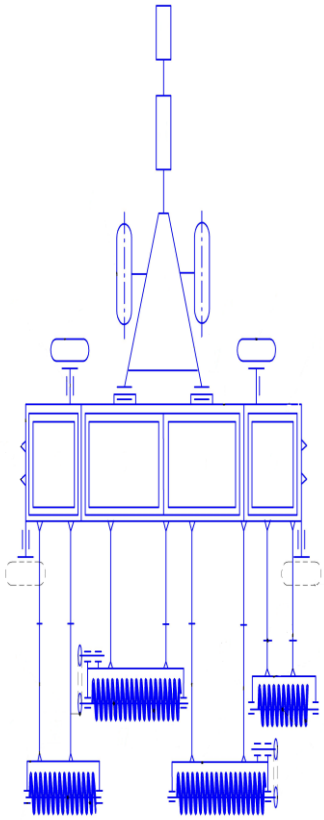


Figure 4: Proposed MFU scheme for the mechanization of crop production: a) MFU for plowing and basic fertilization; b) MFU for harrowing with top dressing; c) MFU for sowing with application of fertilizers; d) an assembly for harvesting straw with straw pressing.



a)



c)

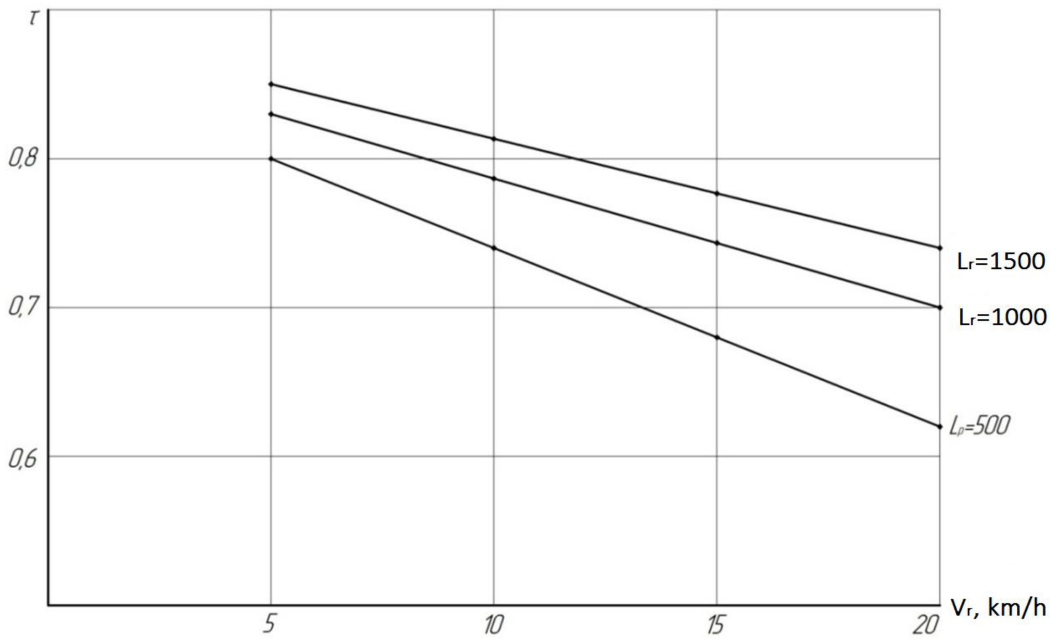
A multi-functional arable unit (Figure 4a) with a reversible plow replaces single-unit aggregates for basic fertilization and for leveling the soil after plowing. Some time was wasted when loading the fertilizer hopper, in general, a reduction in costs and an increase in labor productivity were provided for the work package. According to our calculations, labor costs are reduced 3.7 times, and operational ones - 1.6, metal consumption - almost 2 times, energy intensity - 2.2 times. Thus, all the indicators of the effectiveness of arable MFU contribute to reliable competitiveness. MFU for harrowing with simultaneous application of mineral fertilizers (Figure 4b) is also more efficient than single-acting machines.

The unit for soil treatment with fertilizer, comprising working bodies for soil treatment and fertilization, characterized in that as a working body for soil treatment used rotary harrow containing a frame on the top of which is mounted with the possibility of trailed attachment to the power supply, with supports having bearings, fixing the shaft, which is fixed to the flat discs with a uniform pitch, and discs with a uniform pitch fixed loose teeth, with each tooth has a mounting, rod and working part, where the mounting and rod in the cross section have the shape of an ellipse, and the working part is made in the form of an elliptical cone, the conical surface of which forms its lateral surface, also the rod and the working part of the tooth have on the side two parallel cutting edges no more than 2 mm thick, and each tooth of the harrow is fixed to its mounting part on a flat disk with a uniform pitch so that the direction of the curvature of the curvature of the working part of the tooth is made in the form of a logarithmic spiral, and as an organ for fertilizing the hopper, on the side of which the mounting units are installed for a detachable connection to the body of the energy medium, with an adjustable flap, and on the lower side of the hopper an additional drive motor is installed, the shaft of which is connected by a kinematic connection to the scattering disk, while the adjustable flap and the drive motor are electrically and independently connected to the control panel having mounting units for installation in the cabin of the energy vehicle.

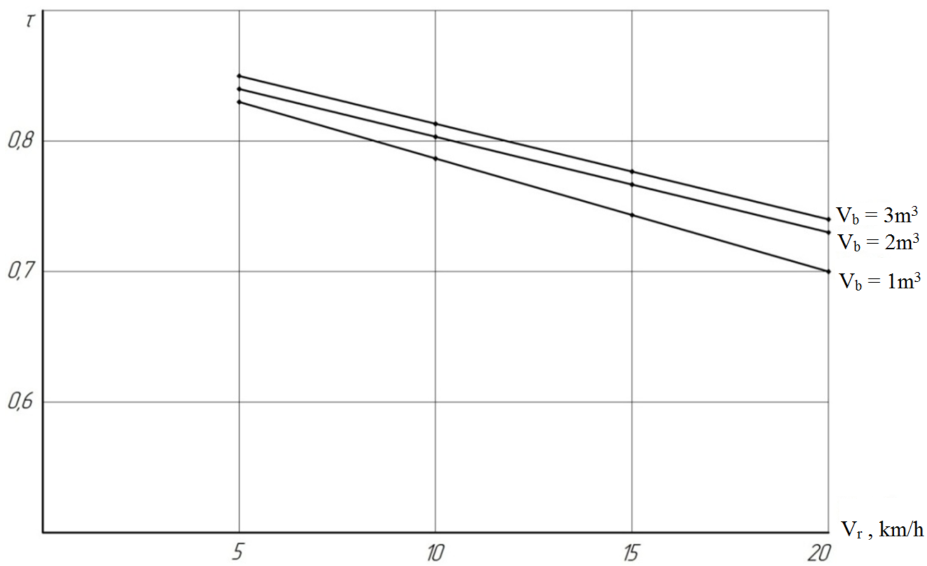
The optimal parameters of MFU for harrowing crops with top dressing are substantiated. Figure 5 shows the dependence of the coefficient τ of the use of the shift time on the operating speed V_r for different lengths of the L_r race. As follows from this figure, the coefficient τ increases with increasing length of the L_r rut and the capacity of the fertilizer hopper V_b.

As a result of the obtained dependences of the utilization factor of the shift working time from the working speed of the aggregate V_r for different lengths of the L_r run and the capacity of the mineral fertilizer hopper V_b, it is established that the values of this coefficient for the MTZ-80 + MPH-5.6 aggregate vary in the interval = 0.62 ... 0.85 for run lengths 500 ... 1500 m with a bunker V_b = 1 m^3, and for a run length of 1000 m, depending on the capacity of the hopper 1 ... 3 m3 varies in the range 0.7 ... 0.85.

Improvement of the sowing MFU (Figure 4c) in our work is aimed at keeping the quality of sowing for meeting the requirements for cost reduction, as well as in providing the required amount of a soil layer of optimal density with seeded seeds on an equalized bed and an upper loose thickness of 2.0 ... 2, 5 cm with broken porosity to prevent loss of moisture from the seed bed.



a)



b)

a) addiction τ from V_r at various L_p; b) addiction τ from V_r and V_b

Figure 5: Dependence of the coefficient τ of the use of the shift time on the MFU parameters and the length of the gong L_r

Such requirements can be ensured only by the screw press roller KVSH, which, creating a compacted layer at the depth of the seeding of wheat seeds 3.0 ... 3.5 cm, above it creates loose without bore holes to prevent moisture evaporation of the lower layers. Ring-shoe rollers do not provide such a structure of a compacted layer of soil, even leaving some areas unattached, which increases moisture loss and reduces yield. In our country, many already use screw rollers KVSH-15 instead of ring-spur. But it is also very important to combine the simultaneous operations with the sowing of seed seeds separately from them (in addition to the starting dose) of a certain number of elements of phosphorus P, potassium K and nitrogen N in accordance with the programming of the crop and the already applied fertilizer dose for basic tillage.

The latter on the MFU scheme (Figure 4d) is intended for harvesting grain crops at the same time as pressing straw.

The shortcomings of harvester harvesting of cereals and other agricultural crops are very widely covered in literary sources. The main ones are grain losses of up to 10% of the crop, its traumatization and soil compaction by heavy machines, reducing its fertility, low probability of setting threshing combines for optimal operation, high cost of grain harvesting, especially by foreign harvesters. Further increase in the productivity of combines is accompanied by an increase in the energy intensity of the harvesting process, their mass and price. An important drawback is the traumatization of grain by harvesting machines, the size of which is 5 percent in the whole country, and the microdamage is 48 [10, p.170], and this is an indirect loss of yield. The list of these shortcomings can be continued, but the presented one already indicates the urgency of the problem of harvester harvesting and the need to switch to new alternative MFUs. One of them is shown in Figure 4d, but MFU is more preferable in such a composition on the basis of trailed non-motor combines as the Canadian MN-130.

The proposed resource-saving technology for harvesting winter barley MFU as part of the combine harvester TORUM-740 with a straw baler PRF-180 provided high efficiency in comparison with separate operations. Our researches proved the advantage of the rotor modification of the threshing-separating device in comparison with the bile. The macro damage to the grain decreases tenfold and the microdamage by 8.3% (from 29.5% to 21.2). This indicates the need to switch to the rotor modification of the combine as part of the MFU. Technical and economic indicators of the proposed technology are much more preferable compared to single-operation machines. Labor costs and metal consumption are reduced by 4.1 times, fuel consumption and energy intensity - 1.3 times, operating costs - 1.2 times. The economic effect per 1 hectare of harvesting area was 1205 rubles. MFU harvesters for complex harvesting operations, in addition to straw balers, can also be equipped with soil cultivating tools for primary soil cultivation simultaneously with grain harvesting, direct seeding seeders for intermediate crops, etc. High efficiency can also be expected here.

Thus, multifunctional aggregates are an important reserve for increasing the efficiency of crop production. In the table, we calculated the performance indicators for the proposed MFU.

Table 1: Indicators of the effectiveness of the proposed MFU in comparison with single-purpose machines (times)

Offered by MFU	Performance Indicators			
	increase in labor productivity	lower operating costs	reduction of metal consumption	decrease in energy intensity
Arable	3,7	1,6	2,0	2,2
For harrowing with fertilizer application	4,7	1,2	4,8	1,7
Sowing with fertilization and packing	experimental research			
Cleaning with straw pressing	1,6	1,2	1,6	1,3

CONCLUSION

To further increase labor productivity and competitiveness of crop production, it is required to move to a rational system of machine-based multifunctional aggregates (MFU) instead of single-operation machines. The proposed MFU compositions for soil cultivation, harrowing with mineral fertilizers, sowing of grain crops with basic and sowing fertilization, for harvesting grain crops with simultaneous pressing of straw can provide an increase in labor productivity up to 4.8 times, a decrease in the metal and energy intensity processes in 2 ... 2,2 times, operating costs in 1,2 ... 1,6 times.

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