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ОЦЕНКА И ВЫБОР МАШИННО-ТРАКТОРНЫХ АГРЕГАТОВ ПРИ КУЛЬТИВАЦИИ ПО ЭНЕРГЕТИЧЕСКИМ ЗАТРАТАМ

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Представлены материалы по оценке и выбору машинно-тракторных агрегатов по критериям минимизации затрат на их производство и эксплуатацию (суммарная удельная энергоемкость МТА на его производство и эксплуатацию) и максимальной производительности при выполнении технологического процесса культивации почвы. Установлено, что номенклатура технологических машин для проведения технологического процесса культивация при мощности мобильных энергетических средств до 110 л.с. определяется культиваторами типа КПС-4, КБМ-4,2 с использованием тракторов JD5620, AGCO MF3640, ЮМЗ-6, ЛТЗ 95Б, JD6020, МТЗ-80/82, МТЗ-920, Беларус-900, Беларус-921, Беларус-923, Deutz Agrofarm 430 и МТЗ-1025. Они имеют суммарные удельные энергоемкости использования с обозначенными технологическими машинами на минимальном уровне, производительность – на максимальном. В диапазоне мощностей тракторов от 110 до 145 л.с. целесообразно использовать культиваторы КШУ-5, КШУ-6, КПС-8П с мобильными энергетическими средствами New Holland T6050 Delta, CASE IH Maxxum 125, JD 6130D, JD 6135, МТЗ-1221, Беларус 1220, ЛТЗ-155 и МТЗ-1222, имеющими также максимальную производительность при минимальном уровне суммарных удельных энергоемкостей на их производство и эксплуатацию. Выявлено, что при применении культиваторов типа КШУ-12, КБМ-7,2П, КБМ-10,8П, Лидер-6Н, АПК-7,2, RTS-1831, КПО-7,2, KORUND 8/900 (мощность энергетического средства до 150–210 л.с.) по обозначенным критериям эффективности целесообразно использовать тракторы Т-150К, МТЗ-1523, ХТЗ-121, ХТА 200-10, Беларусь 1525, ХТЗ 17221, Terrion ATM 3180, Deutz Fahr Agrotron 165.7, JD 7030, ATM 4200 Terrion, МТЗ-2022. Установлено, что для использования культиваторов Лидер-7,2Н, Лидер-8 по обозначенным критериям минимизации затрат энергии и максимальной производительности требуются тракторы мощностью до 210–240 л.с. JD 7830, JD 7930, New Holland 7060, Deutz Fahr Agrotron L720 DCR, Claas Axion 850.

Ключевые слова: технологические процессы, машинно-тракторные агрегаты, формирование, удельная энергоемкость

EVALUATION AND SELECTION OF MACHINE-TRACTOR UNITS DURING CULTIVATION BY ENERGY COSTS

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The materials on evaluation and selection of machine-tractor units by the criteria of minimization of their production and operation costs (total specific energy intensity of MTU for its production and operation) and maximum productivity in carrying out the technological process of soil cultivation are presented. It has been established that the range of technological machines for carrying out the

technological process "cultivation" with the power of mobile power plants up to 110 hp is determined by cultivators such as KPS-4, KBM-4.2 type using tractors JD5620, AGCO MF3640, UMZ-6, LTZ 95B, JD6020, MTZ-80/82, MTZ-920, Belarus 900, Belarus-921, Belarus-923, Deutz Agrofarm 430 and MTZ-1025. They have the total specific energy intensity of use with the designated technological machines at the minimum level, and the productivity at the maximum. In the power range of tractors from 110 to 145 hp it is advisable to use cultivators KSHU-5, KSHU-6, KPS-8P with mobile power tools New Holland T6050 Delta, CASE IH Maxxum 125, JD 6130D, JD 6135, MTZ-1221, Belarus 1220, LTZ-155 and MTZ-1222, which also have the maximum productivity at the minimum level of the total specific energy consumption for their production and operation. It has been found that when using cultivators of the type KSHU-12, KBM-7.2P, KBM-10.8P, Leader-6N, APC-7,2, RTS-1831, KPO-7.2, KORUND 8/900 (power of the energy means up to 150-210 hp), according to the indicated efficiency criteria, it is advisable to use tractors T–150K, MTZ-1523, HTZ-121, HTA 200-10, Belarus 1525, HTZ 17221, Terrion ATM 3180, Deutz Fahr Agrotron 165.7, JD 7030, ATM 4200 Terrion, MTZ-2022. It has been established that for the use of cultivators Leader-7.2N, Leader-8, according to the indicated criteria for minimizing energy consumption and maximum productivity, tractors with a power of up to 210-240 hp like JD 7830, JD 7930, New Holland 7060, Deutz Fahr Agrotron L720 DCR, Claas Axion 850 are required.

Keywords: technological processes, machine-tractor units, formation, specific energy intensity

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INTRODUCTION

One of the main issues faced by agricultural producers in the implementation of technological processes in crop cultivation technologies is the formation of a rational composition of machine-tractor units (MTU). At the present time the market of agricultural machinery offers a wide choice of mobile power units and technological machines, equipped with the necessary devices for operation, control and management of tillage processes, sowing of seeds of agricultural crops, application of various forms of mineral fertilizers, etc. However, this causes a significant increase in the cost of purchased machinery and the corresponding financial costs in its operation. In addition, the choice of a rational composition of MTU is complicated by a large volume of calculations in the formation of technological maps for the cultivation of crops in determining the direct operating costs due to the increased nomenclature of technical support of technological processes.

In this regard, at the initial stage it is advisable to form machine-tractor units according to the criteria of minimizing the cost of their production and operation (total specific energy intensity of MTU for its production and operation) and maximum productivity in performing the corresponding technological processes [1-10].

The research of the leading scientists of Siberia in the implementation of technological

processes of tillage, application of liquid forms of mineral fertilizers, sowing of grain crops in the conditions of the Siberian region is aimed at solving the issues of reducing energy consumption in the production of agricultural products [11-15].

When considering the issues of energy saving in technological modules of crops cultivation, it is necessary to take into account the fact that technological processes of the same functional orientation must be performed in full and in the required time interval. This kind of dual goal requires a logical solution, taking into account the assessment of the significance of factors affecting the choice of machine-tractor aggregates.

The purpose of the work is to choose a rational composition of machine-tractor units on energy indicators in the implementation of the technological process of cultivation.

The research objective is to evaluate the effectiveness of the technological aggregates according to the criterion of minimization of total specific energy inputs during the technological process of cultivation.

MATERIAL AND METHODS

The method for determining the anthropogenic energy of production and operation of mobile energy vehicles and technological machines is described by known dependencies in accordance with recommendations [1-7] [16]. In this case we are talking about assessing the efficiency of using machine-tractor aggregates by two quality indicators: the minimum cost of their production and operation (total specific energy intensity of MTU for its production and operation) and the maximum productivity when performing the corresponding technological processes. It is advisable to solve the presented two-criteria task as follows:

– determination of anthropogenic energy of production and operation of mobile energy vehicles and technological machines;

– determination of energy consumption of the operating personnel;

– determination of specific (per 1 hour of work) energy intensity of tractors, technological machines and couplings in the performance of the corresponding technological process.

Anthropogenic energy of production and operation of mobile energy facilities and technological machines is determined by the formula

$$E^{j}_{A} = E^{j}_{dr} = (E^{j}_{dl} + E^{j}_{m} + E^{j}_{c} + E^{j}_{t}) / W^{j}_{ops}, \quad (1)$$

where E^{j}_{A} – energy costs in the implementation and selection of a particular (j-ro) technological process; E^{j}_{dr} - specific direct energy consumption for the implementation of j-ro PPM, MJ/ha; E^{j}_{dl} - energy inputs of live labor during implementation of the j-th CHP, MJ/h; Ej m + E^{j}_{c} + E^{j}_{t} - energy intensity of technological machines, couplings, tractors respectively per 1 hour of shift time, MJ/h; W^{j}_{ops} - output per shift of MTA in the j-th CHP, ha/h.

Energy costs of the operating personnel

$$E^{j}_{j} = \frac{n^{\cdot}_{nj} \times A^{\cdot}_{j} + n^{\cdot\cdot}_{nj} \times A^{\cdot\cdot}_{j}}{W^{j}_{ops}},$$

where $n^{\cdot}_{nj}$, $n^{\cdot\cdot}_{nj}$ – he number of main workers (tractor drivers, combine operators, drivers) and indirect labor (sowers, tractor drivers, loaders), respectively; $A^{\cdot}_{j}, A^{\cdot}_{j}$– energy equivalents of

[1]Milaev P.P. System biogeoenergetic analysis of the agricultural production processes: Methodological recommendations. Novosibirsk, 2005. 80 p.

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labor costs of the main and indirect labor, MJ/person/h.

The following energy equivalents for labor, MJ/person/h were accepted: tractor drivers, combine operators, drivers - 60.8; indirect labor - 33.3 (see footnote 4).

The specific energy intensity of tractors, technological machines and couplings is calculated by the following formulas (3) – (4):Удельную энергоемкость тракторов, технологических машин и сцепок определяем по формулам (3) – (4):

$$E_t = \frac{M_t \cdot A_t}{100}\left[\frac{a_t}{T_{nt}} + \frac{a_{кт} + a_{тт}}{T_{zt}}\right]; \quad (3)$$

$$E_m = \frac{M_m \cdot A_m}{100}\left[\frac{a_m}{T_{nm}} + \frac{a_{mt}}{T_{zm}}\right], \quad (4)$$

where E_t, E_m are the specific energy intensity of tractors and technological machines accordingly per 1 hour of work, MJ/h; A_t, A_m - norm of deductions for renovation of tractors and technological machines accordingly, %; Mrt - norm of deductions for renovation of tractors, %; att, atm - norms of deductions respectively for current repair, maintenance and storage of tractors and technological machines, %; Tnt,Tnm - normative annual load of tractors and technological machines respectively, h; T_{zt}, T_{zm} - zonal annual load of tractors and technological machines respectively, h.

The energy equivalent of 1 kg of physical weight of tractors and cars is taken at the level of 142.2 MJ, that of agricultural machinery - 116.1, the norms of the annual load, deductions for renovation, overhaul and current repairs, maintenance and storage of agricultural machinery are taken from the recommendations (see footnotes 4, 6).

RESULTS AND DISCUSSION

The assortment of technological machines for carrying out the technological process of cultivation is presented quite capacious. In each drawbar category of mobile energy equipment, the main type of use of these machines is defined with the presentation of the total specific energy intensity of both technological machines and mobile energy equipment of the corresponding class and the productivity of an aggregate as an integral part of the evaluation of its use efficiency.

When using mobile power tools up to 110 hp the following main technological machines are used: cultivators KPS-4, KBM-2,1 and KBM-4,2 (see Fig. 1).

Analysis of the material shows that with almost the same productivity (4,0-4,3 ha/h), cultivators KPS-4 and KBM-4,2 have at least a twofold advantage over the KBM-2,1 cultivator. In addition, the total specific energy intensity of the use of technological machines and mobile power equipment is in a similar ratio. In this connection two kinds of technological machines with the following mobile power equipment are offered for realization: JD5620, AGCO MF3640, UMZ-6, LTZ 95B, JD6020, MTZ-80/82, MTZ-920, Belarus-921, Belarus-923, Deutz Agrofarm 430 and MTZ-1025, having the total specific power consumption of the mentioned technological machines use at the minimum level, productivity - at the maximum.

When using mobile power equipment with the power of 110-145 hp it is advisable to use the following technological machines which form the basis in the presented class of tractors: cultivators Stepnyak-4,2, KSHU-5, KSHU-6 and KPS-8P.

It should be noted that Stepnyak-4,2 coupled with mobile energy equipment has a high (almost 2 times) total specific power capacity compared to the cultivators of this class (see Fig. 2). Besides, its productivity is 1,8-2,0 times lower than that of the indicated cultivators. In this connection for practical realization we take cultivators KSHU-5, KSHU-6 and KPS-8P in

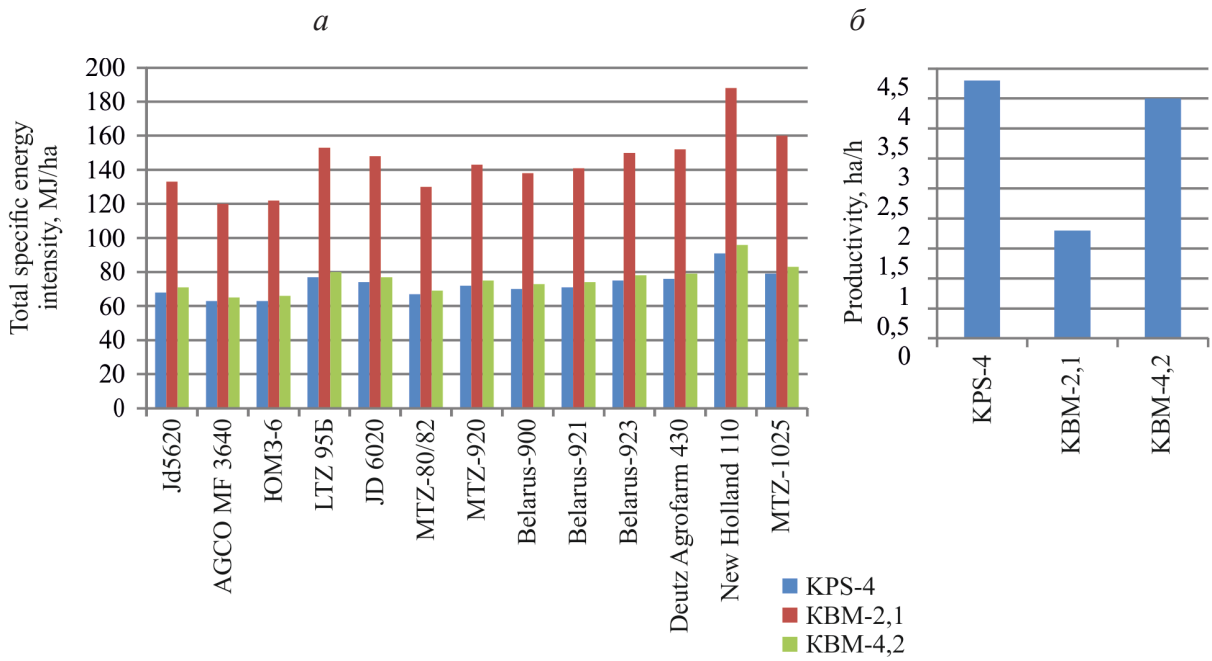

Рис. 1. Суммарная удельная энергоемкость использования технологических машин (*а*) и производительность при культивации (*б*) (мощность трактора до 110 л.с.)

Fig. 1. Total specific energy intensity of using technological machines (*a*) and productivity during cultivation (*б*) (tractor power up to 110 hp)

the aggregate with New Holland T6050 Delta, CASE IH Maxxum 125, JD 6130D, JD 6135, MTZ-1221, Belarus-1220, LTZ-155 and MTZ-1222 mobile power vehicles. It is inexpedient to use RTM-160 tractor with this class of technological machines because of high total specific power consumption.

For mobile power equipment with the power of 150-210 hp there is a wide range of technological machines (cultivators): KBM-6, KBM-7,2P, KBM-10,8P, Leader-4, Leader-6N, APK-7,2, RTS-1831, Stepnyak-5,6, KPO-7,2, KSHU-12, KORUND 8/900, KPE-3,8. This list can be continued (see Fig. 3).

Initial assessment of the appropriateness of using technological machines according to the minimum total specific energy intensity revealed that the lowest value of it has the cultivator KSHU-12 (61-69 MJ/ha). Then follow KBM-6 and KBM-7,2P cultivators according to this indicator (86-106 and 88-104 MJ/ha respectively).

There is no denying the possibility of operating other technological machines in the technological process of cultivation (it is more related to the sustainability of economic development of agricultural producers), but we recommend a scientifically sound rational approach to the choice of mobile power tools and related technological machines by the criterion of the lowest total specific energy intensity of their use.

For the final evaluation and selection of a promising variant of the unit with the designated criterion, it is advisable to further evaluate their use by the productivity of the compiled units (ha/h) (see Fig. 4).

For the practical implementation according to the mentioned criteria of minimization of energy consumption and maximum productivity of the unit created on this base it is reasonable to use KSHU-12 cultivator in combination with mobile energy vehicles T-150K, MTZ-1523, HTZ-121, HTA 200-10, Belarus 1525, HTZ 17221, Ter-

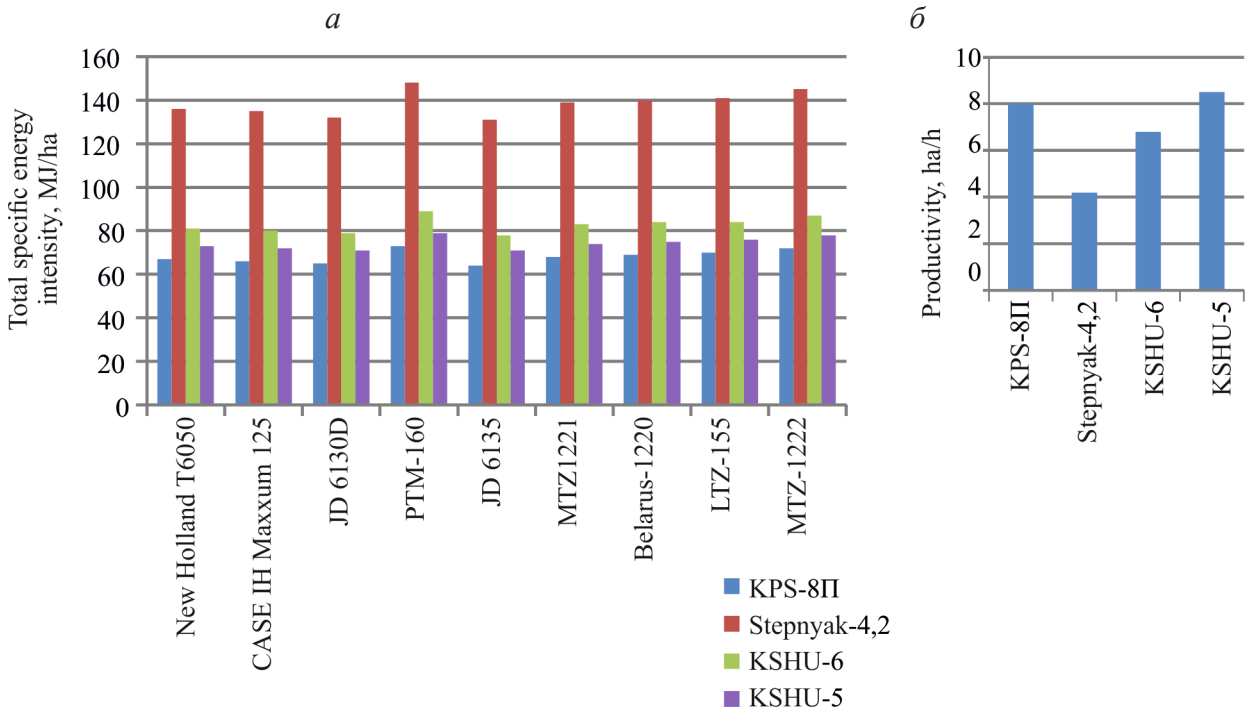

Рис. 2. Суммарная удельная энергоемкость использования технологических машин (*а*) и производительность при культивации (*б*) (мощность трактора 110–145 л.с.)

Fig. 2. Total specific energy intensity of using technological machines (*a*) and productivity during cultivation (*б*) (tractor power 110-145 hp)

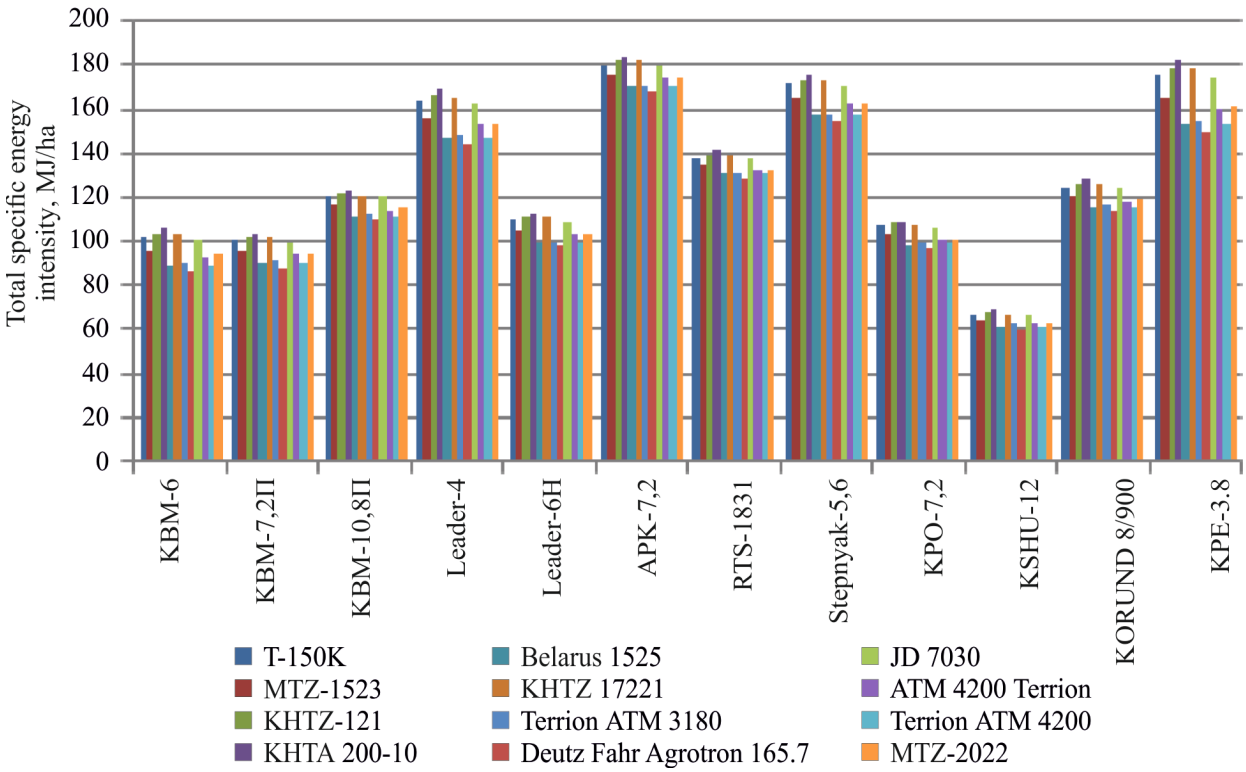

Рис. 3. Суммарная удельная энергоемкость использования технологических машин при культивации (мощность трактора 150–210 л.с.)

Fig. 3. Total specific energy intensity of using technological machines during cultivation (tractor power 150-210 hp)

rion ATM 3180, Deutz Fahr Agrotron 165.7, JD 7030, ATM 4200 Terrion, MTZ-2022.

A separate position is occupied by a number of cultivators with acceptable in this area performance: KBM-7,2P, KBM-10,8P, Leader-6N, APK-7,2, RTS-1831, KPO-7,2, KORUND 8/900 (88-104, 110-123, 98-113, 171-184, 129-141, 171-182, 114-128 MJ/ha) while operating the same mobile power equipment.

Increasing the power of mobile power tools up to 210-240 hp ensures the operation of wide-cut cultivators of Leader-7,2H, Leader-8 and Prostor-5,4 types. The unambiguous leader by the minimum of the total specific energy intensity of the use of technological machines is the cultivator Leader-7,2H (111-119 MJ/ha) (see Fig. 5).

According to this evaluation criterion, the values are quite close when using Lider-8 and Prostor-5,4 cultivators (147-156 MJ/ha), which exceed the total specific energy intensity when using Lider-7,2H cultivator.

Evaluating the effectiveness of these technological machines by the second criterion - productivity - it should be noted that the productivity of cultivators Leader-7,2H, Leader-8 is 1,7 and 1,8 times higher than that of the cultivator Prostor-5,4.

Taking into account the above material, we recommend for practical implementation in this class of mobile power tools JD 7830, JD 7930, New Holland 7060, Deutz Fahr Agrotron L720 DCR, Claas Axion 850, cultivators Leader-7,2H and Leader-8.

Further increase of the power of mobile power tools (up to 240-280 hp) enables to operate wide-cut cultivators such as KBM-14,4P, KD-720ML, Stepnyak-7,4, Stepnyak-10 and KPSH-9.

In terms of minimum energy consumption in the operation of the presented technological machines, the most representative is the cultivator KPSH-9 (96-108 MJ/ha) (see Fig. 6).

All the above-mentioned cultivators have energy intensity of their use exceeding the values of 145 MJ/ha and more. It is important to note that by productivity KPSH-9 is almost equal to KBM-14,4P and Stepnyak-10 cultivators (see Fig. 7).

Evaluating the stated material by the criteria of total specific power consumption of technological machinery and productivity in their operation, it is advisable to use KPSH-9 cultivator in the unit with mobile energy equipment MTZ-2522, K-700A Slavich, K-701 Slavich, MTZ-2822 and Terrion ATM 5280.

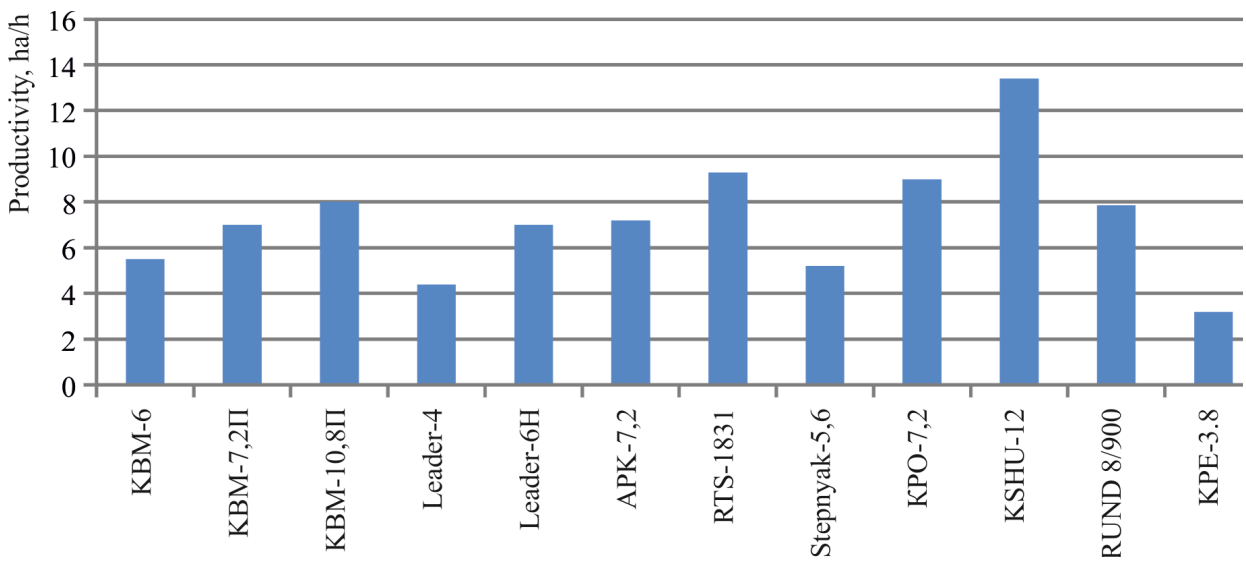

Рис. 4. Производительность технологической машины при культивации (мощность трактора – 150–210 л.с.)

Fig. 4. Process machine productivity during cultivation (tractor power - 150-210 hp)

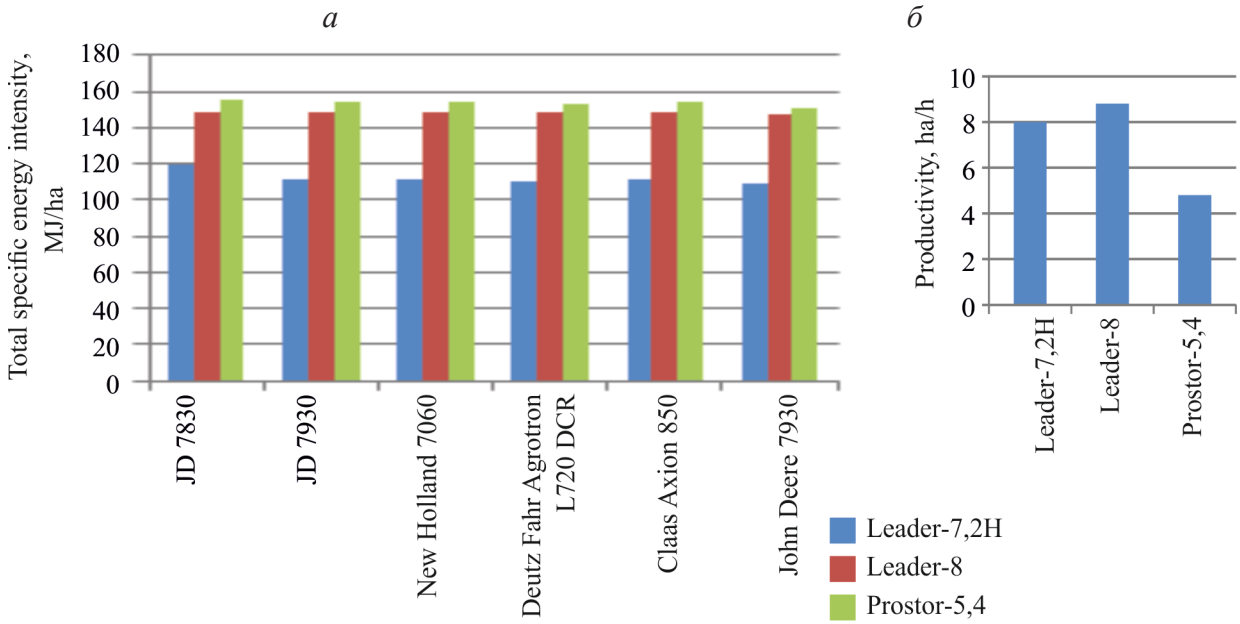

Рис. 5. Суммарная удельная энергоемкость использования энергетических средств при культивации (*а*) при производительности технологического средства (*б*) (мощность трактора 210–240 л.с.)

Fig. 5. Total specific energy intensity of using technological machines during cultivation (*a*) at their productivity (*б*) (tractor power 210-240 hp)

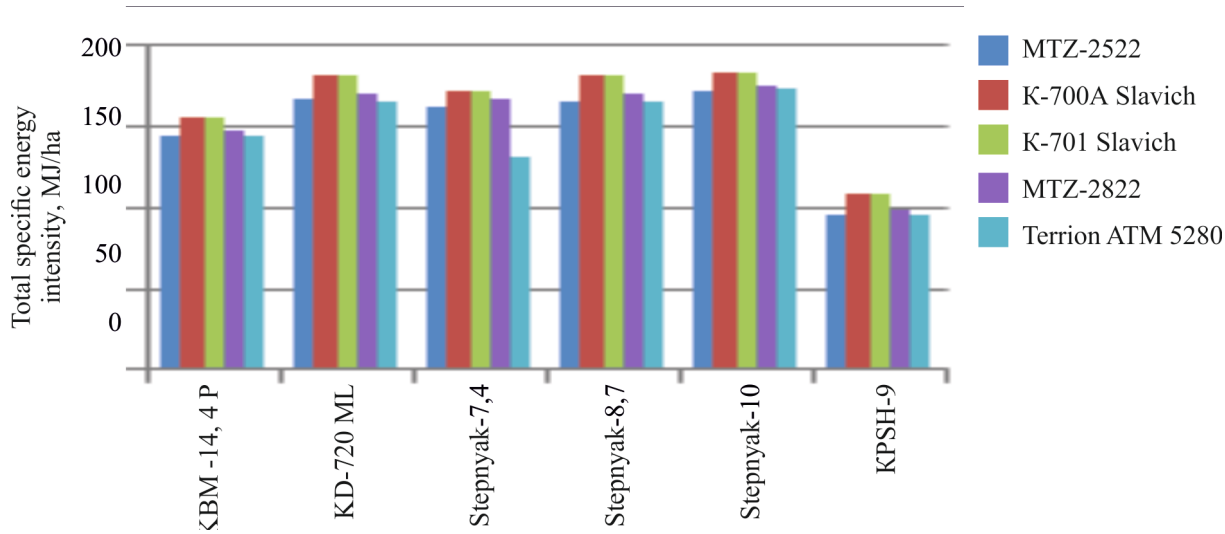

Рис. 6. Суммарная удельная энергоемкость использования технологических машин при культивации (мощность трактора 240–280 л.с.)

Fig. 6. Total specific energy intensity of using technological machines during cultivation (tractor power 240-280 hp)

CONCLUSIONS

1. At the initial stage of formation of machine-tractor units it is advisable to evaluate the effectiveness of their acquisition by the criteria of minimizing the cost of their production and operation (the total specific energy intensity of MTU for its production and operation) and the maximum productivity when performing the corresponding technological process.

2. The use of the proposed methodological approach to the evaluation and selection of the rational composition of a machine-tractor aggregate provides a 20-25% reduction in material costs for the purchase of technical support

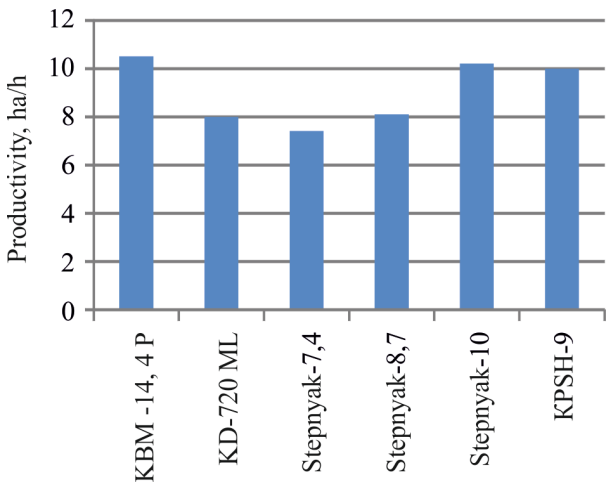

Рис. 7. Производительность технологической машины при культивации (мощность трактора 240–280 л.с.)

Fig. 7. Productivity of technological machines during cultivation (tractor power – 240–280 hp)

of technological processes in the technologies of cultivation of crops.

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