

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

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**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'skokhozyaystvennyye 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 a brand 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 K3C-740 "Polesiye" combine harvester

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

$$V_p = \frac{q \cdot K_3 \cdot 10}{B \cdot \beta \cdot Y \cdot (1 + \delta)}, \quad (1)$$

where  $V_p$  is the working speed, m/s;

$q$  – throughput capacity, kg/s;

$K_3$  – coefficient of zonal conditions;

$B$  – header width, m;

$\beta$  – coefficient of the header width use;

$Y$  – crop yield, t/ha;

$\delta$  – 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:

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

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

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

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

$$C_k = \frac{C_3}{W_{cm}} + \Pi_y, \quad (3)$$

where  $C_k$  – composite costs, \$/h;

$C_3$  – operating (direct) costs, \$/h;

$\Pi_y$  – 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:

$$C_3 = C_a + C_p + C_o + C_T, \quad (4)$$

where  $C_a$  – depreciation costs, \$/h;

$C_p$  – repair costs, \$/h;

$C_o$  – labor costs, \$/h;

$C_T$  – 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:

$$\mathcal{D} = \mathcal{D}_{onm} \cdot \left( \frac{W_6}{W_p} - 1 \right), \quad (5)$$

where  $\mathcal{D}$  – the number of days accompanied by losses, days;

$\mathcal{D}_{onm}$  – number of optimal days for harvesting, days;

$W_6$  – performance rate of a reference combine, ha/h (t/h);

$W_p$  – the productivity of the

compared combine, ha/h (t/h).

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

$$\Pi_y = K_n \cdot C_n \cdot \mathcal{D} \cdot Y, \quad (6)$$

where  $\Pi_y$  – losses from incomplete harvest, \$/ha;

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

$C_n$  – purchase price, \$ 120/ton.

$Y$  – 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-530 combine 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.

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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.