

The experimental research of combine harvesters

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Abstract

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The paper presents results of the experimental research of a middle-size combine harvester when used for harvest of winter wheat and spring barley in heavy harvest conditions. Based on the results obtained, it was possible to determine the effect of field conditions on the crop mass flow in combine harvester, grain losses, fuel consumption, and combine harvester field performance. It was found that grain moisture content and conditions of the crop stand have a significant effect on the work indicators of the combine harvester when compared with its technological parameters and crop mass flow.

Keywords: grain losses; fuel consumption; combine harvester field performance

As stated by KUTZBACH and QUICK (1999) the main processes in a modern harvester are gathering and cutting, threshing, separating, cleaning, and material handling. Currently, designers of the combine harvesters pay more attention to the improvement of the quality of control process, its automatic control, improve the trafficability of the chassis and the environment protection. They argue that an increase in engine power increases the throughput of the combine harvester. Engine power of the combine harvesters equipped with the classic straw walkers already exceeded 295k W/400 HP, and hybrid and axial – closer to 440 kW/600 HP

(SRIVASTAVA et al. 2006). But the throughput of the combine harvester is associated not only with the power of the engine, and it is more closely connected with the separation deck area, straw walker and cleaning mechanism capacity.

According to the FAO Report (FAO 2014) in Ukraine, the 2014 aggregate cereal production is estimated at about 61.9 million tonnes marginally below 2013 year's record level and around 25% above the five-year average. This output reflects near-record yields, following favourable weather conditions during the cropping season, which more than offset a slight contraction in the planted area compared to

last year. Due to the global climate changes, more specific heavy rainfall and winds, it is necessary to harvest heavy laid crop stands, crops with grain moisture content over 20%. Therefore, in each region the work of the combine harvesters should be evaluated in order to determine the relationship between working conditions and allowable mass flow to the combine harvester threshing mechanism, the other process parameters, grain losses, fuel consumption and performance. Reliable data are needed for the planning of harvest strategy.

On large farms in Ukraine and Latvia the grain crops and rape are harvested by using of high-capacity combine harvesters (ŠPOKAS et al. 2005; ŠPOKAS 2006). Dominating are hybrid combine harvesters equipped by two axial rotary straw separators instead of straw walkers, which are used on conventional combine harvesters. Combine harvesters with axial threshing-separating device, after design improvement of the axial drum, are increasingly used for harvest of the grain crops and rape with increased grain moisture content (ŠPOKAS et al. 2005; ŠPOKAS, 2006). For the harvest in heavy climate conditions and for the grain maize harvest during October combine harvesters equipped with TERRA-TRAC undercarriage and steered driving axle are used. In Hungary, there were obtained results confirming that combine harvester with axial threshing-separation mechanism has caused 4-times lower wheat grain damage when compared with the combine harvester equipped with straw walker (KELEMEN et al. 2005). The content of impurities in the grain was lower by 0.94% and the difference in fuel consumption was negligible. With the axial threshing-separation mechanism less grain losses were obtained when compared with the straw walker (RADEMACHER 2003; MIU, KUTZBACH 2007), due to the fact, that the separation area of the axial mechanism is 2,4-times bigger than area of the threshing concave of the tangential threshing mechanism.

Currently there are prevailing the combine harvesters equipped with the straw walker with the medium capacity. Grain losses and grain damage are used as basic indicators for evaluation of their technological function (EIMER 1988; FEIFFER et al. 2005). These indicators have a close relation to the design of the threshing mechanism (WACKER 1985), its technological parameters (ŠPOKAS 2006), as well as to the crop mass flow (ŠPOKAS et al. 2005), its structure and moisture content (WACKER 2003). Within one modification, many combine harvest-

ers equipped with straw walkers differ from one another only in engine power, grain tank capacity and acquisition price. However, it is necessary to state that the value of the real combine harvester throughput of many currently manufactured combine harvesters with straw walkers depends not only upon the engine power but also upon the other indicators, which should be studied and exactly determined.

The aim of the research was to determine the relationship between the harvest quality indicators and technical parameters of the combine harvesters having medium throughput and equipped with the straw walkers.

MATERIAL AND METHODS

The experiments were conducted in field conditions and during experiments medium capacity combine harvester New Holland TX 68 (New Holland, Turin, Italy) and CLAAS Lexion 570 (Claas KGaAmbH, Harsewinkel, Germany) were used having the following parameters: working width of the cutter bar 6 m; high performance patented APS system with a pre-accelerator in the threshing unit; diameter of the threshing drum 0.6 m; width of the threshing drum 1.7 m; wrapping angle of the threshing drum 142°; threshing concave separation area 1.26 m². Grain from the straw is separated by six-sections straw walker having a separation area 7.48 m², and from the chaff – cleaning by two sieves having a surface area 5.8 m²; max. engine power 191 kW/260 HP.

Biometric parameters. Within field experiments two crops were harvested: winter wheat and spring barley. On the harvest day, a small plot was chosen within a field with a surface area 0.25 m², and all stalks of the grain crop were cut with 5 repetitions. In the laboratory during analysis, the following parameters were determined: the weight of the stalk samples and weight of the stubble having height 150 mm, average number of grains in the ears, their weight, 1,000-grain weight and also biological grain yield.

Winter wheat cv. Türkis created a high crop stand, whereas wheat cv. Skagen – due to the rain and unreasonable fertilizing – created a laid crop stand. Crop stand of the spring barley cv. Cruiser was completely laid, the large-size grains were prevailing in the ears, the weight of the 1,000 barley grains was higher than that of wheat grains.

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The grains of the barley were soft, the 1,000-grain weight reached the level of 35.2 ± 0.28 g.

Grain damage. Within field experiments 2 kg-samples of the grain were taken from the auger flow during transport of grain to the grain tank. From the samples having a weight 0.050 kg, the damaged grains were separated and average amount of the damaged grain was determined with 5 repetitions.

Grain losses. Grain losses behind the straw walker and grain cleaning mechanism were determined. During combine harvester movement the two collecting trays (surface area 0.018 m^2) were put under the combine harvester, two collecting trays were put close to a driving wheel (at 1 m and 2 m distance). In the laboratory, grain from each sample was separated and the grain losses behind the straw walker and cleaning mechanism were determined.

Fuel consumption. Combine harvester Caterpillar C6.6 engine (Caterpillar, Peoria, USA) is equipped with the integrated device allowing to measure the immediate fuel consumption in l/h. It is possible to determine the fuel consumption related to harvest of 1 ha and 1 t of the grain. On-board computer recorded the values of forward speed of the combine harvester, technological parameters of the threshing mechanism, harvested area, amount of the grain harvested, grain moisture content, as well as fuel consumption. The fuel consumption was differentiated during morning, during day and during evening. The data characterizing fuel consumption were compared between harvest of standing crop stand and heavy-laid crop stand of wheat and barley.

RESULTS AND DISCUSSIONS

Grain losses behind the straw walker and cleaning mechanism, grain damage, fuel consumption

and combine performance are considered as basic criteria for evaluation of the combine harvester work in field condition. All above criteria are very closely connected with the working conditions.

Meteorological conditions

During the experimental studies maturing crops and harvesting conditions were unfavourable. Average air temperature reached only 16.2°C , precipitations were 41.6 mm. Then, the temperature rose to 19.4°C , precipitation decreased to 13.1 mm. But because of the high grain moisture and straw moisture content ($> 25\%$) harvesting of grain crops was delayed. Next, precipitations of 49.6 mm were recorded and the average temperature was 18.7°C . The harvest of the winter cereals crops started when the grain moisture content reached the level of about 20%.

Biometric parameters of the grain crops

Functions of the combine harvesters were evaluated during harvest of the two varieties of winter wheat and spring barley (Table 1).

Grain losses behind the straw walker and cleaning mechanism

Allowable values of grain losses behind the straw walker and cleaning mechanism are 0.5% in standard field conditions and 1.0% in unfavourable field conditions (ŠPOKAS 2006). During harvest of the winter wheat cv. Türkis, the mean grain moisture content was 20%, and the straw moisture content

Table 1. Biometric parameters of the grain crops

Parameters	Units	Grain crops cultivars			
		winter wheat		spring barley	
		Türkis	Skagen	Quench	Cruiser
Number of productive stalks	pcs/m	694.70 ± 27.10	764.00 ± 83.3	906.00 ± 50.10	730.70 ± 161
Length of the stalk to the ear	m	0.71 ± 0.01	0.75 ± 0.02	0.66 ± 0.02	0.55 ± 0.01
Number of grains in ear	pcs	46.60 ± 1.69	30.20 ± 0.99	22.90 ± 2.02	19.97 ± 0.67
Weight of 1,000 grains*	g	44.22 ± 0.35	45.30 ± 0.37	35.20 ± 0.28	45.94 ± 0.29
Biological grain yield *	t/ha	8.45 ± 0.40	8.30 ± 1.70	7.300 ± 1.40	6.70 ± 1.04

*grain moisture content 14%

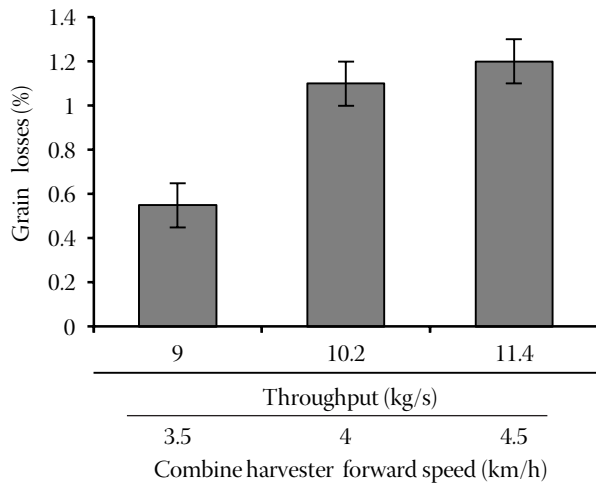


Fig. 1. Grain losses behind the straw walker and cleaning mechanism during harvest of the winter wheat cv. Türkis: threshing drum speed $n_b = 830$ rpm, fan speed $n_v = 1,270$ rpm, clearance between threshing drum rasp bars and threshing concave $a = 8$ mm, clearance between shutters of the upper sieve $b_1 = 12$ mm, clearance between shutters of the bottom sieve $b_2 = 6$ mm, grain yield $A_g = 8,45$ t/ha, grain moisture content $U_1 = 20.5\%$

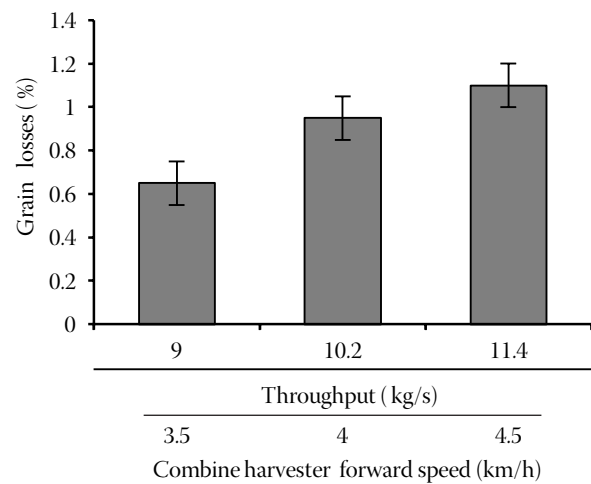


Fig. 2. The grain losses behind the straw walker and cleaning mechanism during harvest of the winter wheat cv. Skagen: threshing drum speed $n_b = 750$ rpm, fan speed $n_v = 1,230$ rpm, clearance between threshing drum rasp bars and threshing concave $a = 9$ mm, clearance between shutters of the upper sieve $b_1 = 9$ mm, clearance between shutters of the bottom sieve $b_2 = 5$ mm, grain yield $A_g = 8.3$ t/ha, grain moisture content $U_1 = 17.0\%$

was 30%. High grain yield (8.45 t/ha) and wheat grain moisture created the constrains for combine harvester forward speed and crop mass flow to the combine harvester. For the throughput 9 kg/s of the wheat crop mass, the grain losses reached the level of 0.5% (Fig. 1). When the throughput of the wheat crop mass was increased by 1 kg/s, the grain losses behind the straw walker and cleaning mechanism were higher than 1%. Combine harvester throughput at the level 9.5 kg/s can be considered as an optimal value for the harvest of the wheat crop mass with higher moisture content.

During harvest of the laid winter wheat cv. Skagen, at the grain moisture content 17%, corrections of the technological parameters of threshing mechanism and cleaning mechanism were provided (Fig. 2). In order to reduce the amount of impurities in grain, the clearances among the shutters on the upper sieve were diminished at the value of 9 mm. It was found that in given harvest conditions the optimal combine harvester throughput for the harvest of winter wheat was 9.5 kg/s (Fig. 2). Combine harvester grain damage was $0.66 \pm 0.21\%$.

During experiment the effect of the clearances between shutters of the upper sieve on the grain losses was studied. It was found that the increase of

the clearances from 9 to 14 mm allowed to decrease the grain losses only at the level of 0.13%.

During the harvest of barley bigger amount of straw particles came to the cleaning mechanism and the straw was less compacted on the straw walker when compared with the harvest of wheat. Therefore, it is very often necessary to reduce the combine harvester forward speed even in the case when barley crop stand is not laid.

It was found that in normal harvest conditions of the spring barley cv. Quench with grain moisture content 14.2%, the grain losses limit behind the straw walker and cleaning mechanism (0.5%) was not exceeded when combine harvester throughput reached 9 kg/s. By increasing of the clearances between shutters on the upper sieve from 9 to 13 mm the grain losses were decreased at the level of $0.24 \pm 0.13\%$.

Crop stand of the spring barley cv. Cruiser was very laid (lodged) and the grain moisture content was 17.8%. At the max. possible forward speed of the combine harvester 5.5 km/h and combine harvester throughput 8.7 kg/s during harvest of the barley crop mass, the grain losses behind the straw walker and cleaning mechanism reached the value of $0.44 \pm 0.14\%$.

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Table 2. Fuel consumption of the combine harvester engine

Crop	Average grain moisture content (%)	Fuel consumption		
		(l/h)	(l/ha)	(l/t)
Wheat cv. Türkis	18.8	44.57 ± 4.02	22.94 ± 1.22	2.72 ± 0.18
Wheat cv. Skagen	17.2	41.02 ± 4.25	29.03 ± 4.85	3.47 ± 0.41
Barley cv. Quench	16.7	49.81 ± 8.22	16.77 ± 1.47	2.36 ± 0.41
Barley cv. Cruiser	17.6	42.86 ± 2.74	17.28 ± 0.53	2.54 ± 0.16

When evaluating the work of combine harvester with medium-size throughput during the harvest of the winter wheat and spring barley, it was found that combine harvester working conditions have a bigger effect on the grain losses behind the straw walker and cleaning mechanism when compared with the effect of crop mass flow to the combine harvester. For the harvest of winter wheat and spring barley with higher crop mass moisture content the optimal value of the combine harvester throughput is 9.0 kg/s.

Grain damage

According to ŠPOKAS 2006 it is necessary to state that grain damage depends upon the moisture content of the threshed crop mass, upon the technological parameters of the threshing mechanism and also upon the crop mass flow. The acceptable limit of the grain damage is 1%. During the harvest of winter crops with the higher moisture content the value of grain damage $0.44 \pm 0.17\%$ was reached in case of winter wheat cv. Türkis, and $0.61 \pm 0.24\%$ in case of winter wheat cv. Skagen. Grain damage of the spring barley cv. Cruiser with moisture content 17% reached the value of $0.74 \pm 0.11\%$ and with moisture content 14,2%, the value of grain damage was $2.74 \pm 0.71\%$. It was found that grain moisture content and peripheral speed of the threshing drum rasp bars have the biggest effect on the grain damage. Increase of the combine harvester throughput (increase of the crop mass flow) caused the decrease of the grain damage.

Fuel consumption

Fuel consumption related to the harvest of 1 t of the grain materials can be used as a main indicator. Work of the medium size combine harvester is

considered as efficient when fuel consumption related to the harvest of 1 metric tonne of the grain is not higher than 2 l, and 2.5–3 l during harvest in unfavourable harvest conditions (FEIFFER et al. 2005).

During experiments the fuel consumption of combine harvester engine was recorded in the moment when grain tank was full of grain. Combine harvester was observed during all day and the data characterizing the time of grain tank filling and corresponding value of fuel consumption were obtained at least for 10 tanks.

It was found that fuel consumption of the combine harvester engine related to harvest of one hectare with the heavy laid crop stand of the winter wheat cv. Skagen with high moisture content reached 29.03 ± 4.85 l/ha and for harvest of 1 metric tonne of grain it was 3.47 ± 0.41 l/t (Table 2).

During harvest of the winter wheat cv. Türkis, the fuel consumption related to 1 t of grain was decreased by 0.75 l/t. For the harvest of the 1 metric tonne of the grain of spring barley the fuel consumption was decreased by 1 l/t when compared with the harvest of the heavy laid crop stand of wheat variety cv. Skagen. The data characterizing the fuel consumption of the combine harvester engine can be used for analysis and planning of the fuel supplies determined for harvest works.

Combine harvester performance

The results obtained during our field experiments confirmed that combine harvester performance depends upon the cutter bar working width, grain yield and also upon the combine harvester forward speed which is determined by field conditions and acceptable level of grain losses behind the straw walker and cleaning mechanism. Grain losses behind the cutter bar are connected with the skills and qualification of the combine harvester operator.

During harvest of the winter wheat cv. Türkis with higher crop mass moisture content, the combine harvester performance during 1 h of the technological time was 1.94 ± 0.14 ha/h and it was 16.42 ± 1.53 t of grain. When the heavy laid crop stand of wheat cv. Skagen was harvested – the combine harvester performance was 1.48 ± 0.42 ha/h and 12.12 ± 2.67 metric tonnes of grain were harvested. When harvesting spring barley cv. Quench from 11 a.m. until 2 p.m., the combine harvester performance was 1.71 ± 0.43 ha/h and 13.07 ± 3.27 t of grain were harvested (grain moisture content 18.6%), and from 2 p.m. until 5 p.m. the combine harvester performance was 2.57 ± 0.41 ha/h and 19.90 ± 3.27 t of grain were harvested (grain moisture content 15.5%). Without regard to the fact that until 9 p.m. the grain moisture content was decreased at the level 15.5%, the combine harvester performance was decreased to the value 2.63 ± 0.24 ha/h and 19.43 ± 1.49 t of grain were harvested. It was found that during summer approximately from 6 p.m. the increase of the relative air humidity started with adequate increase of the straw moisture content and grain losses behind the straw walker.

CONCLUSION

The results obtained within our experimental research significantly confirmed the general state of knowledge that apply to a wide range of harvesting conditions. The crop stand before harvest – crop stand lodging rate and moisture content have a large effect on the grain losses behind combine harvester straw walker and cleaning mechanism, when compared with the changes of crop mass flow to the combine harvester and other harvest technology parameters. For the combine harvesters with middle class throughput our results are new.

Results of the field experimental research confirmed that for the harvest of the laid crop stands and crops stands with higher moisture content the combine harvester throughput 9.0 kg/s can be considered as a most rational. Based on the research results obtained, it can be stated that the increase of the clearance between shutters of the upper sieve from 9 mm to 14 mm allows to decrease grain losses behind straw walker and cleaning mechanism by 0.13% in case of wheat and by 0.24% in case of barley.

Values of the grain damage do not exceed acceptable limit 1%, when wheat and barley grain moisture content was lower than 17%. When the barley grain moisture content was 14.2 %, the grain damage reached the value of 2.74%. With a decrease of the grain moisture content, it is necessary to change technology parameters of the combine harvesters in order to save the level of the limits of the grain damage.

The research of the fuel consumption of the combine harvester engine related to the harvest of 1 ha of the laid wheat crop stand confirmed that fuel consumption was 29.03 ± 4.85 l/ha. For the harvest of 1 metric tonne of the grain, the fuel consumption was 3.47 ± 0.41 l/t in case of wheat and in case of barley the fuel consumption was lower by 1 l/t.

The experimental research also confirmed that during 10 hours in a day, the barley grain moisture content decreased by 3.1% and it caused an increase of combine harvester performance by 0.92 ha/h, grain harvest increased by 6.36 t/h and fuel consumption related to harvest by 1 t was decreased by 0.16 l/t.

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