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Impact of the CEMOS AUTOMATIC intelligent system on the field performance and energy efficiency of a CLAAS LEXION 770 combine harvester

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Abstract. Efficient management of combine harvesters is a key factor in modern precision agriculture, where automation and intelligent control systems play an essential role in optimizing operational performance and energy efficiency. This study presents a comparative analysis of the CLAAS LEXION 770 combine harvester operating with and without the CEMOS AUTOMATIC intelligent optimization system during wheat harvesting (Avenue variety). Field experiments were conducted to evaluate key performance indicators, including grain losses, fuel consumption, engine load, and throughput capacity under real harvesting conditions. The results show that the use of the CEMOS AUTOMATIC system improved fuel efficiency by 7–10%, reduced grain losses by 15–20%, and provided more stable machine operation compared with manual control. Furthermore, the intelligent control algorithm optimized the settings of threshing and cleaning systems in real time, resulting in improved productivity and reduced operator workload. The findings confirm that the integration of automated optimization systems such as CEMOS AUTOMATIC significantly enhances the energy efficiency and sustainability of modern harvesting operations.

Key words: combine harvester, CEMOS AUTOMATIC, precision agriculture, operational performance, wheat harvesting.

INTRODUCTION

Combine harvesters play a crucial role in grain harvesting and have become increasingly automated in recent years (Masek et al., 2017). The high demands on modern grain harvesters and rapidly changing field and environmental conditions have led to the development of advanced automated control systems aimed at improving performance and reducing fuel consumption (Masek et al., 2015; Burlaka et al., 2021).

Grain harvesters no longer only collect data and facilitate the operator's work, but also independently optimize their work to achieve maximum efficiency (Masek et al., 2015; Ivanyshyn et al., 2019; Burlaka et al., 2021; Bomoi, 2023). The continuous technological development of combine harvesters has significantly increased their level of automation and integration of intelligent systems (Goltyapin et al., 2021). This development ensures a stable technological process, improves working conditions, reduces soil compaction, and promotes the widespread use of computer-based control systems. At the same time, the increasing complexity of these systems presents challenges for operators (Yanxin Yin et al., 2018; Burlaka et al., 2021).

The continuous improvement of grain harvesters leads to an increase in their technical level and integration of innovative technologies such as Dynamic Cooling, Laser Pilot, Autopilot and Telematics, which contribute to more efficient and precise harvesting (Böttinger, 2008; Coen et al., 2008; Savickas et al., 2019; CLAAS, 2024).

Another innovative development implemented in grain harvesters is the system for continuous monitoring and adjustment of the parameters of the harvesting process, Cemos Automatic (Escher et al., 2014; Goltyapin et al., 2021). It is a fully automatic system for configuring the combine harvester for separation and cleaning functions. It uses numerous sensors to monitor the parameters of the machine and adjust its operation in real time (Escher et al., 2014). Terörde & Neu (2014) developed a mathematical model that describes in real time the behaviour of the technological process of a grain harvester equipped with the CEMOS (CLAAS Electronic Machine Optimization System) system, as well as its advanced version CEMOS AUTOMATIC.

A number of scientists have contributed to the design, research and analysis of grain harvesting machines (Escher et al., 2014; Iliiashyk et al., 2016, Miu, 2016, Savickas et al., 2019; Tihanov, 2019; Tihanov et al., 2021; Zhang et al., 2022; Hossen, 2023). However, there are limited studies focused on the CEMOS AUTOMATIC optimization system implemented in CLAAS LEXION harvesters.

Modern intelligent systems in agricultural machinery are increasingly based on advanced data processing, sensor fusion, and adaptive control algorithms (Zhang et al., 2022; Hossen, 2023; Gu et al., 2025; Chen et al., 2025). In combine harvesters, such systems integrate information from multiple sensors, such as grain loss sensors, crop flow sensors, and engine load indicators - to continuously evaluate operational performance (Yanxin Yin et al., 2018). Based on this real-time data, automated optimization systems can adjust key machine parameters, including threshing intensity, cleaning airflow, and forward speed, in order to maintain optimal efficiency under varying field conditions (Nadai et al., 2020; Hossen, 2023; Padhiary et al., 2025; Jiang et al., 2025). These intelligent control approaches reduce the dependence on operator experience and enable more consistent and energy-efficient harvesting performance. Despite these technological advancements, there is still a need for more field-based experimental studies evaluating the real operational impact of such systems under practical conditions.

The objective of this study is to analyze the operational performance and energy efficiency of two CLAAS LEXION 770 combine harvesters, one equipped with the CEMOS AUTOMATIC system, under real wheat harvesting conditions. This study contributes to filling this gap by providing a comparative analysis under real field conditions.

MATERIALS AND METHODS

Study area and techno-operational characteristics of the grain harvesters

The experiment was conducted in July 2023 on the land of an agricultural holding in the village of Tihomirovo (Radnevo municipality), in the central part of the Republic of Bulgaria. Coordinates of the experimental plot 42°14'57"N25°50'06"E (Fig. 1, a). The experimental field was relatively flat, with no significant slope variations that could affect machine performance. The soil type in the area is characterized as typical chernozem, ensuring uniform working conditions for both combine harvesters during the experiment.

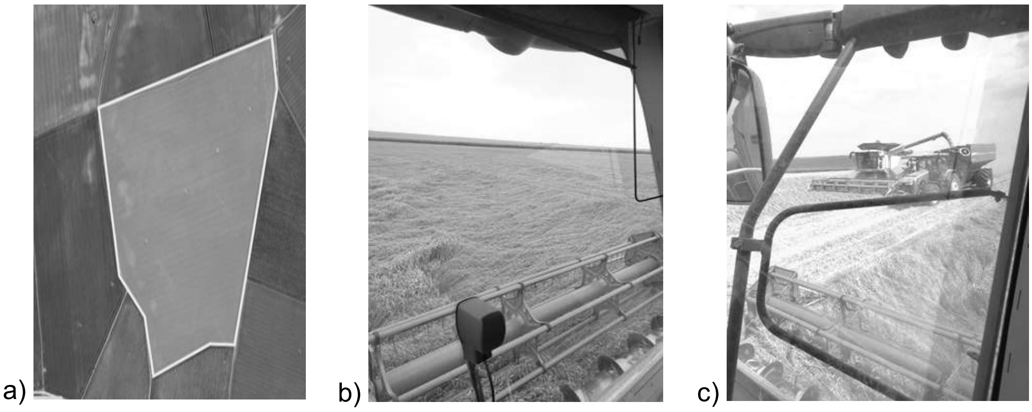


Figure 1. Experimental area village of Tihomirovo (42°14'57"N25°50'06"E).

The study involved two CLAAS LEXION 770 combine harvesters (Fig. 2, a), one operating in standard configuration and the other equipped with the CEMOS AUTOMATIC optimization system (Fig. 2, b).

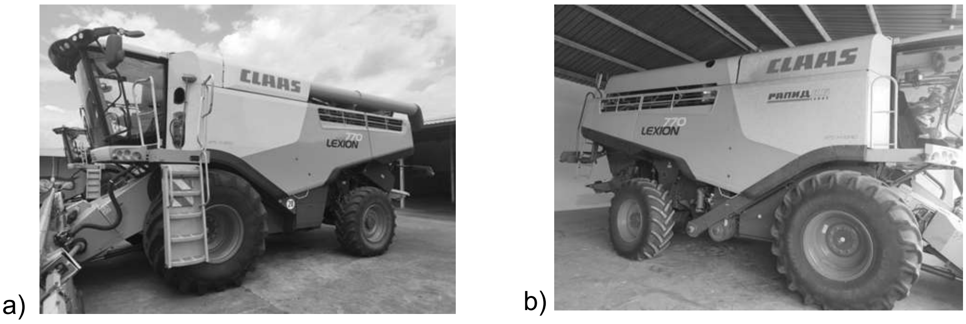


Figure 2. Grain harvesters CLAAS LEXION 770: a) Standard configuration; b) with CEMOS AUTOMATIC.

The experiment comprised a harvesting process in which grain harvesters operated at a fixed speed of 4 km h^{-1}. The studied area was 107 ha, sown with wheat Avenue variety. Before harvest, the average measured crop moisture was 10–11%, and the crop condition was heavy lodging (Fig. 1, b and c). The average yield per hectare was 946 kg. The experiment started at 10:00 a.m. and ended at 2:00 p.m. Before the start of the harvesting process, the tanks of both grain harvesters were filled with fuel to the top.

The technical and technological parameters for both studied grain harvesters are presented in Table 1. The parameters of the grain harvesters are completely identical, a difference is observed in the equipment with electronic optimization systems. One of the machines is equipped with the Cemos Automatic and Cruise pilot systems.

Table 1. Technical characteristics of the studied harvesters and electronic optimization systems of the harvesters

Parameters	CLAAS LEXION 770 with CEMOS AUTOMATIC	CLAAS LEXION 770 (standard configuration)
Engine	Mercedes benz 15.6 L 576 horse power	Mercedes benz 15.6 L 576 horse power
Transmission	semi-automatic	semi-automatic
Drive	4×4 Wheel	4×4 Wheel
Threshing mechanism	APS HYBRID	APS HYBRID
Grain bunker volume	11,500 L 8,400 t	11,500 L 8,400 t
Fuel tank folume	1,150 L	1,150 L
Ad blue	yes	yes
Cemos automatic	yes	no
Cruise pilot	yes	no
Laser pilot	yes	yes
Chambers	yes	yes
3d sieve cleaning system	yes	yes
Header	Vario 900	Vario 900
Cebis main monitor	yes	yes

Methodology of conducting the experiment

The combine harvester settings are made as follows:

In the standard CLAAS LEXION 770 combine harvester, the operating parameters are set manually via the CEBIS display installed in the cabin. The operator enters the required operating parameters before starting the working day, and these settings usually remain unchanged. As a result, with increased load, losses may occur.

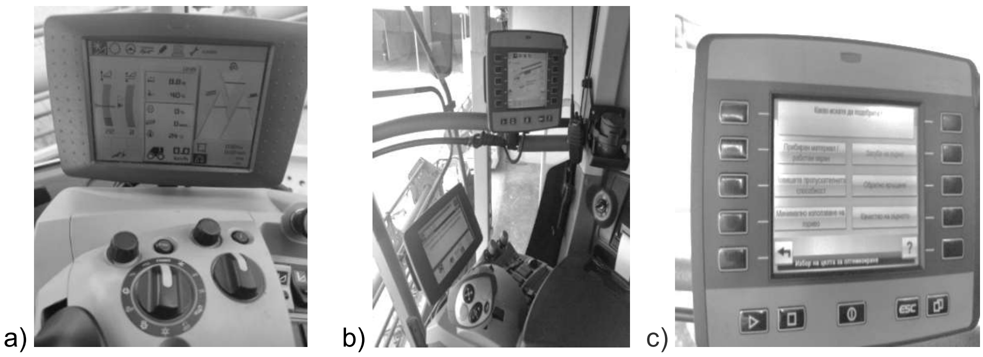


Figure 3. Display for programming the grain harvesters.

Unlike the standard CLAAS LEXION 770, the CLAAS LEXION 770 equipped with the CEMOS AUTOMATIC system monitors machine parameters in real time via the in-cab display (Fig. 3. a and 3, b) and automatically adjusts them according to the operating conditions. Before starting work in the field, when the ‘assistant system’ is activated, questions appear on the control monitor that the operator must answer (Fig. 3, c). Among the main settings are: crop type, crop condition, relative humidity, as well as the operator’s preferences for priority settings.

For simplicity, the two machines are hereafter referred to as 'Standard Lexion' and 'CEMOS AUTOMATIC Lexion'.

Conducting field experiments

To determine the presence of differences in some of the operating parameters of the studied Claas Lexion 770 grain harvesters, the following operating indicators were monitored in parallel for both harvesters during the study:

– Working hours of both grain harvesters, ha - The time of the start of the harvesting process and its completion is detected
– The harvested area of both grain harvesters, ha - It is recorded by the harvester monitor, after the completion of the work process (before the start of the harvest the monitor is reset)
– Harvester performance per hour, t h^{-1}
– Total harvested quantity by the harvester, t
– Fuel consumption L ha^{-1}
– Total fuel consumed, L
– Average speed of the harvester, km h^{-1} - Monitored by the harvester monitor
– Time to fill the hopper, min - Recorded with a stopwatch
– Rotor losses, % - The data are taken from the monitor in the harvester
– Sieve losses, % - The data are taken from the monitor in the harvester
– Rotor revolutions, min^{-1} - The data are taken from the monitor in the harvester
– Drum revolutions, min^{-1} - Data are tracked from the monitor in the harvester
– Fan revolutions, min^{-1} - Data are tracked from the monitor in the harvester
– Counter gap, mm - Data are tracked from the monitor in the harvester
– Sieve position, mm - Data are tracked from the monitor in the harvester
– Engine load, % - Data are tracked from the monitor in the harvester.

The selected indicators were used to evaluate the operational performance, energy efficiency, and stability of the combine harvesters during the harvesting process. Parameters such as fuel consumption and engine load were analyzed to assess energy efficiency, while grain losses and throughput were used as key indicators of harvesting performance. Machine settings (e.g., rotor speed, fan speed, sieve position) were monitored to evaluate the adaptive response of the CEMOS AUTOMATIC system under varying field conditions.

Data analysis

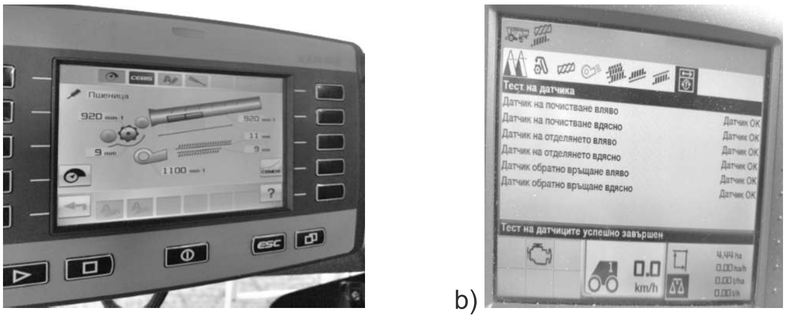
Statistical processing of the collected data was performed by using the SPSS software package. Descriptive statistics (mean, standard deviation, minimum and maximum values) were calculated for the main operational indicators of the two grain harvesters, including performance (t h^{-1}) and operating speed (km h^{-1}).

The normality of the data distribution was checked by using the Kolmogorov-Smirnov and the Shapiro-Wilk tests. To establish statistically significant differences between the machines, t-test for independent samples and UniANOVA analysis were applied.

A correlation analysis was performed to assess the relationship between performance and speed of the harvesters. Non-linear regression models were created describing the predictive relationship between speed and performance. The coefficient of determination (R^2) was used to assess the accuracy of the models.

RESULTS AND DISCUSSION

Cemos Automatic is an electronic automatic optimization system integrated into certain Claas grain harvester models. Its main function is to support the operator in the cabin by offering optimal settings and adapting the machine to the operating conditions. By reducing the complexity of the settings, the Cemos Automatic System facilitates the operator's work and allows for rapid optimization of the operating parameters. The system is controlled and visualized through a special monitor located in the cabin (Fig. 4), which displays the threshing mechanism of the machine and the relevant parameters such as revolutions, dimensions (mm) and other key indicators.



a) b)

Figure 4. Controller for setting and monitoring the Cemos automatic system.

Cemos Automatic continuously collects data from multiple sensors (Fig. 4, b), located on the grain harvester, and maintains constant communication with other automated systems, such as Cruise Pilot. Among the key sensors are those for: grain losses, wheel steering angle, amount of mass entering the inclined chamber, grain moisture, load on the various systems of the machine.

The collected data is fed in real time to the main controller (central computer), where artificial intelligence processes them and automatically optimizes the main components of the threshing mechanism, including: drum revolutions, rotor revolutions, fan speed.

In addition, Cemos Automatic also regulates the speed of the grain harvester during harvesting. Depending on the amount of mass entering the inclined chamber, the system automatically increases or decreases the working speed, maintaining constant communication with the Cruise Pilot for optimal control.

Some performance indicators of two Claas Lexion 770 grain harvesters, one of which is equipped with a Cemos Automatic system, were monitored during the harvesting process at a working speed of the machines of 4 km h^{-1} and regression models were developed revealing the relationship between them. The verification with the Kolmogorov-Smirnov and the Shapiro-Wilk tests shows that the studied parameters performance and speed of the grain harvesters have normal distribution (Table 2). The normality of distribution allows the use of parametric tests.

Table 2. Normality distribution verification of the investigated parameters performance and speed of the grain harvesters - Standard Lexion and Cemos automatic Lexion

	Grain harvester	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Stat.	df	Sig.(p)	Stat.	df	Sig.(p)
Harvester performance, t h^{-1}	Standard Lexion	0.249	9	0.114	0.860	9	0.096
	Cemos automatic Lexion	0.231	9	0.181	0.889	9	0.195
Speed, km h^{-1}	Standard Lexion	0.136	9	0.200*	0.992	9	0.998
	Cemos automatic Lexion	0.140	9	0.200*	0.951	9	0.701

*. This is a lower bound of the true significance; a. Lilliefors Significance Correction.

Table 3 presents the mean values of the calculated parameters of grain harvester performance t h^{-1} and operating speed km h^{-1}. For the Standard Lexion grain harvester, the mean performance value is 30.14 t h^{-1} at a speed of 3.7 km h^{-1}, and for the Cemos Automatic Lexion, the performance is 31.51 t h^{-1} at a speed of 4.23 km h^{-1}. It was observed that the Cemos Automatic Lexion harvester moves 0.5 km h^{-1} faster than the Standard Lexion under the same operating conditions of the machines. Similar studies have shown that grain harvesters equipped with automated adjustment systems achieve higher performance and efficiency compared to standard models. Nadai et al., 2020 investigated the use of artificial intelligence to optimize grain harvester parameters, which leads to improved performance and reduced losses during harvesting.

Table 3. Descriptive statistics of both grain harvesters – Standard Lexion and Cemos automatic Lexion

n = 18	grain harvester	Mean	SD	Min	Max
Harvester performance, t h^{-1}	Standard Lexion	30.14	0.77	29.40	31.80
	Cemos automatic Lexion	31.51	0.99	29.80	32.60
Speed, km h^{-1}	Standard Lexion	3.69	0.31	3.20	4.20
	Cemos automatic Lexion	4.23	0.38	3.50	4.70

* $p < 0.05$.

The results from the UniANOVA test to check for statistically significant differences showed that the two harvesters differed significantly in both performance (Fig. 5, a) and speed (Fig. 5, b).

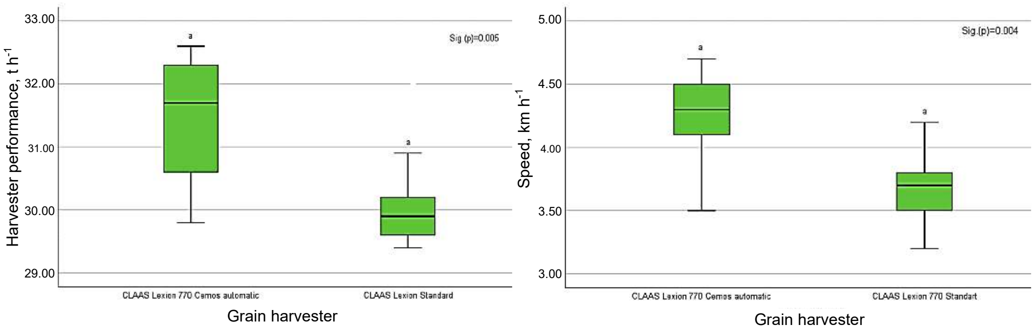


Figure 5. UniANOVA test for the significant differences between the investigated parameters performance a) and speed b) of the grain harvesters - Standard Lexion and Cemos Automatic Lexion. Legend: The same letters (a-a) show significant differences at $p < 0.05$.

Both harvesters showed a very strong correlation between performance and speed (Table 4). Although their correlation coefficients are very close, yet the harvester with the Cemos Automatic Lexion system has a higher correlation coefficient (0.916), indicating that this system is better able to predict performance under different conditions. This is in line with the study by Zhang et al., 2022, who built a system for monitoring the performance of grain harvesters. Through correlation analysis, they investigated the relationships between operating speed, crop density, feed auger torque, conveyor torque, and cylinder torque with performance, building single-variable performance prediction models.

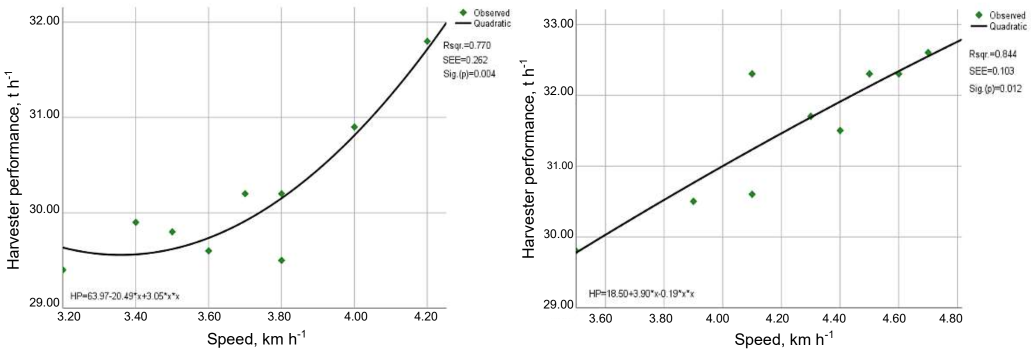
Table 4. Correlation analysis between the investigated parameters performance and speed of the grain harvesters – Standard Lexion and Cemos Automatic Lexion

Standard Lexion		
n = 9	Harvester performance	Speed
Harvester performance	1	0.828*
Sig. (2-tailed)		0.006
Cemos automatic Lexion		
n = 9	Harvester performance	Speed
Harvester performance	1	0.916*
Sig. (2-tailed)		0.002

*Correlation is significant at the 0.05 level (2-tailed).

The non-linear regression equations showing the influence of harvester speed on their performance are presented in Fig. 6. Both combine harvesters have very high coefficients of determination (0.770; 0.844), i.e. 77.0%÷84.4% of the variations in their performance are due to the influence of speed. However, a higher coefficient of determination is observed for the harvester with the Cemos Automatic Lexion system, whichindicates that this system has greater influence on performance depending on changes in operating speed.

In addition, the model error is lower, which proves that the equation for the harvester with the Cemos Automatic Lexion system better describes the relationship between the studied dependencies (speed and performance).



a) Standard Lexion b) Cemos Automatic Lexion

Figure 6. Curve estimation of the calculated predictive regression models showing the relation between performance and speed of the grain harvesters.

The CEMOS model has a lower error and higher predictive value compared to the standard harvester. The results of the study conducted to track the operation parameters of the two grain harvesters are presented in Table 5.

Table 5. Technical comparison of the studied parameters of grain harvesters

	Cemos automatic Lexion 770	Standard Lexion 770
Operating time of the two grain harvesters, h	3.80	3.98
Area harvested by the grain harvester, ha	11.97	11.87
Area harvested per hour, ha	3.38	3.23
Total harvested quantity by the harvester, t	116.67	113.45
Fuel consumption, L ha^{-1}	2.03	2.25
Total fuel consumed, l	243	266
Bunker filling time, min	16	18
Rotor losses, %	Up to 1%	From 1 to 3%
Sieve losses, %	Up to 1%	Up to 1%
Rotor rotations, min^{-1}	850–950	890
Drum rotations, min^{-1}	850–950	830
Fan rotations, min^{-1}	800–1,150	1,100
Counter gap, mm	7–9	8
Sieve position, mm	8–11	9
Engine load, %	37%	40%

In terms of the harvested quantity parameter, there are differences between the performance of the two harvesters. The harvester with the Cemos Automatic system harvested 3.22 t more wheat than the standard model.

In terms of fuel consumption, the harvester with the Cemos system showed a consumption that is 2.2 L ha^{-1} lower than the standard one. The fuel consumed for the entire harvest period for the harvester with the Cemos Automatic system is 22 liters less than for the standard harvester.

Analyzing the bunker filling time, it is noticeable that with the Claas Lexion 770 Cemos the process is 2 minutes faster than with the traditional model.

Despite the fact that both harvesters operate under the same conditions, the harvester with the Cemos Automatic system harvested 1 ha more area than the Claas Lexion 770 standard model.

In terms of rotor losses in the threshing system, in the harvester with the Cemos Automatic system they range up to 1%, while in the standard model they vary between 1 and 3%.

Table 5 shows that the rotor, drum and fan rotations in the Claas Lexion 770 Cemos Automatic vary within certain limits (850–950, 850–950, 800–1,150), while in the Claas Lexion 770 standard these values remain constant (890, 830, 1,100).

The counter gap and the sieve position in the harvester with the Cemos system also vary within certain limits, which favors the operation of the machine, while in the standard model they remain constant.

In terms of engine load, the Claas harvester equipped with the Cemos Automatic system showed a 3% lower load compared to the standard model.

These results indicate that the CEMOS AUTOMATIC system not only improves fuel efficiency and reduces grain losses, but also enhances the dynamic adaptability of machine settings under varying field conditions.

Limitations and future research

The present study has several limitations that should be considered when interpreting the results. The experimental duration was relatively short (approximately four hours), which may limit the ability to evaluate the long-term stability and adaptability of the CEMOS AUTOMATIC system. In addition, the experiments were conducted under specific field conditions, including a single crop type (wheat) and particular lodging conditions, which may restrict the generalizability of the results.

Furthermore, the sample size was relatively limited, which should be taken into account when evaluating the statistical results. While key machine parameters were continuously monitored during the harvesting process, the study did not include a detailed temporal analysis of the dynamic parameter adjustments performed by the CEMOS AUTOMATIC system.

Future research should include multi-season and multi-crop experiments, as well as longer operational periods, to enable a more comprehensive evaluation of the system's robustness and adaptability. Further work is expected to explore the system's performance under different crop types and field conditions.

CONCLUSIONS

Two CLAAS LEXION 770 grain harvesters have been studied – one equipped with CEMOS AUTOMATIC and the other in standard configuration. Field trials were conducted at a fixed speed of 4 km.h^{-1} and identical conditions.

Statistically significant differences were found between the two harvesters in terms of performance and working speed. The harvester with CEMOS AUTOMATIC showed 4.4% higher performance and 2.8% higher harvested quantity. Its fuel consumption was 2.2 L ha^{-1} lower.

Shorter bunker filling time, lower engine load, and lower rotor losses were observed. Correlation analysis showed a strong relationship between speed and performance for both harvesters, with the CEMOS model having higher predictive accuracy and lower error.

The results obtained confirm that automated adjustment and control systems such as CEMOS AUTOMATIC contribute to more efficient and sustainable harvesting, providing advantages in real field conditions.

The results highlight the importance of integrating intelligent optimization systems in modern agricultural machinery as a key factor for improving sustainability and operational efficiency in precision agriculture.

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