ISSN 1846-6168 (Print), ISSN 1848-5588 (Online)
https://doi.org/10.31803/tg-20230712124048

Preliminary communication
Received: 2023-07-12, Accepted: 2023-08-10

Fuel Consumption of the Tractor-Machine Aggregate Conditioned by the Navigation Systems

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Abstract: This paper presents a study regarding fuel consumption, distance traveled and aggregate operation time during agrotechnical harrowing operation with and without a navigation system in the company. The measurement was carried out on an area of 32.41 ha, which was divided into two equal parts (16.205 ha). The researched area was divided into two equal parts using SMS Advance Software. The tractor-machine aggregate consisted of a Claas Axion 830 tractor as the driving part and a harrow as the working part of it. Fuel consumption was monitored via the tractor's display and the volumetric method. A significant difference in fuel consumption was determined for the volumetric method with navigation (9.97%) and without navigation (6.45%). Higher fuel costs were determined when the unit was operated without a navigation system.

Keywords: agrotechnical operation; fuel consumption; harrow; navigation system; tractor

1 INTRODUCTION

Modern agricultural production, in addition to the sufficiency of food production, strives to achieve its competitiveness on the world market by using seeds with high genetic potential, sophisticated machines with the application of modern technologies and scientific achievements. The reduction of input production costs is conditioned by the specifics of the production of an individual crop, the area where it is grown, climatic conditions, etc.

Among other things, the cost of fuel required for the operation of agricultural aggregates has a significant influence on the size of production costs. Therefore, in order to reduce fuel consumption, an attempt was made to introduce new production technologies that reduced the use of agricultural aggregates (reduced processing, direct sowing, etc.).

Tractor-machine aggregates were operated by operators whose quality of work depended on their work experience, overlapping of passages, and ultimately fuel consumption and utilization of working time. This problem is particularly pronounced during work with tractor-machine aggregates of large scope, where the operator is exposed to greater loads, especially in unfavorable working conditions (fog, night work, dust), notes the author [1].

Aggregating is understood as combining the driving and working machine into a harmonious whole, and tractor aggregates are mostly used in agriculture. The coefficient of utilization of the working capacity of machines that do not work in rows and do not have a marker (harrowing, discing, etc.) ranges from 0.90 to 0.96, according to the authors [2]. Therefore, by applying new technologies in production, the influence of the operator's personal abilities and other factors was minimized.

Regular maintenance of agricultural machinery enable timely and quality work with minimal fuel consumption and favorable working conditions with regard to mechanical vibrations, noise and other factors, according to the authors [3].

The author [4] states that on smaller farms where they use working machines with a working reach of three meters (cultivator, grubber), working hours are reduced by up to 15.7 % with fuel savings of up to 8.66 %, and on farms where they use machines with a working reach of six meters, working time is reduced up to 12.6 % and achieves fuel savings of up to 8.28 %. The reason for the reduction in working time and fuel consumption is the smaller overlap of the passages, which with manual navigation amounts to 6.5 to 9.5 % of the entire work that needs to be done. The authors [5] conducted a survey on 55 out of 100 respondents who used autopilot guidance systems in Turkey. The results indicate time savings (80 %), fuel (80 %) and labor savings (50.09 %). The authors [6] state that by applying an automatic guidance system, fuel consumption savings of 8 % can be achieved, that is, from 3 to 7 % of total energy consumption.

The authors [7] state that the use of navigation systems can contribute to the reduction of fuel consumption during the operation of agricultural machinery.

The use of a navigation system in the guidance of aggregates is one of the possibilities of high-quality performance of work with minimal overlapping of passages, better use of working time, reduction of fuel consumption, less soil compaction and less burden on the operator. Investigating the application of navigation systems and automatic steering systems on North Dakota farms, the authors [8] state that the average respondent saves 65 hours of machine operator time, i.e. reduces fuel consumption by 1.647 liters (which is about 6.3 % of fuel consumption) when using the navigation system. Using the automatic steering system can save an average of 75 hours of machine operator time and 1.866 liters of fuel (5.33 % of fuel consumption). The average fuel savings per farm for the navigation system is $1.305 and for the automatic steering the savings are $1.479.

In a study of the economic profitability of applying the technology of precision agriculture and Controlled Traffic Farming in Denmark in the production of four main crops, it was estimated that the Danish gross domestic product will increase by €34 million with the application of the mentioned

technologies, according to the authors [9]. The authors [10] conducted research on a total of 2.200 ha during the application of fertilizers with a navigation system. Potential fuel savings ranged from 0.41 to 0.53 l/ha at a fuel price of 0.86 euros/l.

The aim of this research was to determine the difference in fuel consumption, distance traveled and aggregate operation time during harrowing with and without the use of the tractor navigation system.

2 MATERIALS AND METHODS

The research was carried out through February 23, 2023. in the production areas when closing the winter furrow. The investigated area was 32.41 ha (Fig. 1) and was divided during the measurement into two equal parts (16.205 ha). The investigated area was divided into two equal parts using SMS Advance Software. According to the type, the mentioned plot belongs to coherent soils, the composition of which is the same. A Claas Axion 830 tractor (Fig. 2) with double tires was used during the measurement in combination with a heavy Peck harrow with a working reach of 7 m.

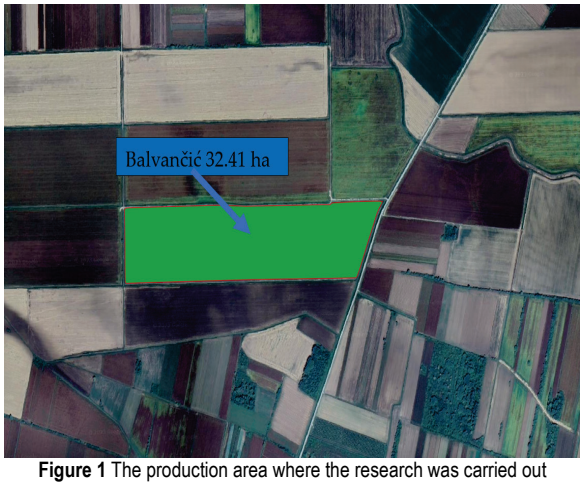

Figure 1 The production area where the research was carried out

Figure 2 The tractor-machined aggregate used to perform the agrotechnical operation of closing the furrow

The closing of the furrow of the first half of the plot was done using Trimble Autopilot navigation with the correction of the RTK of the signal ± 2.5 cm, and the closing of the furrow of the second half of the plot was done without the use of navigation. During the measurement, the following parameters were monitored: working time, distance traveled and total fuel consumption during operation (read on the tractor display and by volumetric method). The volumetric method was carried out by bringing the tractor to a horizontal position and pouring fuel up to a certain mark in the tank before starting work. After that, the tractor with the harrow performed an agrotechnical operation and again brought itself to a horizontal position, and the tank was filled up to the fuel mark. This research is part of a future larger study with regard to fuel consumption, working time and distance traveled by the aggregate when using the navigation system and without using the navigation system.

3 RESULTS

The research results indicate differences in the working time spent (38 minutes) when driving without navigation compared to driving with navigation. Tillage without navigation increases working time consumption by 24.67 % compared to tillage with navigation. It is to be assumed that the greater distance traveled (33.97 km) during operation without navigation is a consequence of the overlap of the passages. The difference in the distance traveled when using navigation compared to working without navigation is (27.51 %), (Fig. 3 and Fig. 4).

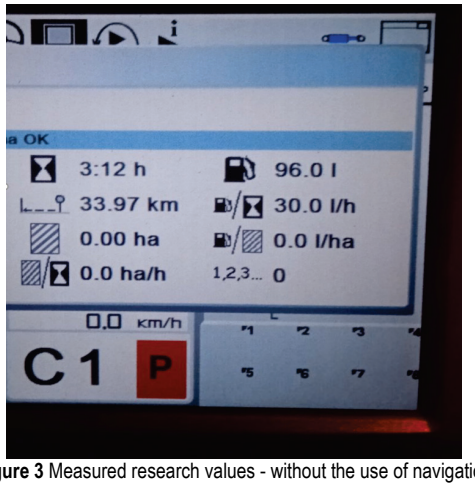

Figure 3 Measured research values - without the use of navigation

The fuel consumption read on the tractor display when working with navigation was 81.2 l, and when working without navigation it was 96.0 l, which is 18.22 % higher consumption than when using navigation. At the same time, during the research, the amount of fuel consumed was checked using the volumetric method, which determined the fuel consumption when working with the navigation system was 89.3 l. Without the navigation system the fuel consumption was 102.2 l, which is 14.44 % higher fuel consumption than when using the navigation system.

Figure 4 Measured research values - with the use of navigation

The results indicate a difference in the consumed fuel by 9.97 % when read on the tractor display and by 6.54 % when calculated by the volumetric method between using the navigation and not using the navigation.

Table 1 Total fuel consumption

Type of work	Fuel cost - display	Fuel cost - volumetric method
With navigation	72.26 €	79.47 €
Without navigation	85.44 €	90.95 €

At the time of the research, the price of blue diesel fuel was 0.89 euros [11], a new regulation on determining the highest retail prices of petroleum products was adopted by the Ministry of Economy and Sustainable Development in Croatia. The fuel costs are shown in Tab. 1. The fuel consumption read on the display per hectare of cultivated area with navigation is 5.01 l and 5.92 l without navigation. Fuel consumption per hectare of cultivated area determined by the volumetric method for working with navigation is 5.51 l and 6.30 l without navigation. The cost of fuel per hectare read on the display with navigation is 4.45 euros and 5.26 euros without navigation. Furthermore, the cost of fuel per hectare determined by the volumetric method when working with navigation is 4.90 euros and 5.60 euros without navigation.

4 DISCUSSION

The higher consumption of working time (24.67 %) during operation without navigation indicates that the aggregate traveled a significantly greater distance (27.51 %) than when using navigation, which, in addition to higher fuel consumption and greater overlap of the passage, will also affect the reduction of the coefficient of utilization of working time, i.e. aggregate effect. All of the above factors depend largely on the operator's work experience and ability. Aggregate management without navigation on large areas is problematic for two reasons: the first is related to the correct measurement of the starting width and the correct first pass of the aggregate, and the second is related to the quality connection of the passes, according to the author [1]. The same problem is pointed out by the authors [12], who state that during the harrowing of 100 ha, the overlap of passages without navigation was found to be 7.04 ha, and 4.94 ha with navigation. Similar results are obtained by the authors [13, 14], when investigating the overlap of passages with and without navigation during spraying, where they determine that the overlap is reduced by using navigation. The authors [15] report fuel and time savings for machines with a working width of 3 m (8.66 % and 15.7 %) and 6 m (8.28 % and 12.6 %) with and without a navigation system, which is similar to the results obtained in this research.

The use of the navigation system resulted in a reduction of fuel consumption by 18.22 % compared to operation without a navigation system, where 5.01 l/ha were used with navigation and 5.92 l/ha without navigation. Fuel costs per hectare of cultivated area are 4.45 €/ha with navigation and 5.26 €/ha without navigation, which is significantly more than 0.93 €/ha reported by the authors [16]. Volumetrically determined fuel consumption with navigation is 5.51 l/ha, and without navigation it is 6.30 l/ha, which gives a cost of 4.91 €/ha and 5.60 €/ha.

A difference in the consumed fuel read on the tractor display was found to be 9.97 % when using navigation and 6.45 % without using navigation, considering the amount of fuel consumed using the volumetric method. These values are significantly higher than the 4.69 % difference stated by the author [17] when measuring the average fuel consumption read from the trip computer with regard to the volumetric method.

Significantly higher fuel consumption determined by the volumetric method in both variants indicates the need for further research into this problem in order to determine the factors that caused it.

5 CONCLUSIONS

Based on the research results, the following conclusions can be drawn:

- higher fuel consumption was found when harrowing without a navigation system,
- a difference was found in the fuel consumption read on the tractor display and the consumption determined by the volumetric method,
- during operation without a navigation system, the aggregate travels a longer distance, which increases the working time,
- higher fuel costs were determined when working without navigation when reading the fuel on the tractor display and when using the volumetric method.

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