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Production Systems

Study of the main operational indicators of a self-propelled sprayer when spraying wheat and sunflower

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Abstract. *An analysis has been made of some operational indicators of a self-propelled sprayer for spraying wheat and sunflower. The data in this study have been gathered and excerpted by the telematic system JD Link. It has been established from the obtained data that 66% of the area when spraying wheat (field A) and 46% of the area when spraying sunflower (field B) had been sprayed at a pre-set consumption rate of 150 l/ha. When spraying wheat (field A) it is evident that the actually applied consumption rate is 147.42 l/ha with actually applied amount of 8563.2 l, while when spraying sunflower (field B) the actually applied consumption rate is 148.33 l/ha with actually applied amount of 11908.10 l. It has been established that the engine rotations in a working engine are almost the same for both fields – 2485.93 min^{-1} in field A and 2495.55 min^{-1} in field B; at idle time the rotations had been the following: when spraying the field with wheat 1481.42 min^{-1}, and when spraying the field with sunflower they were 15 % lower, i.e. 1253.83 min^{-1}. The meane coefficient of engine utilization of the self-propelled sprayer when working, i.e. spraying wheat (field A) has been found to be 58.90%, and when spraying sunflower (field B) it has been 63.60%. From the results obtained it is evident that the consumed amount of diesel in field A has been 28.86% lower that in field B, respectively, with the average diesel consumption in field A being 7.27% lower than in field B.*

Keywords: spraying, telematic systems, self-propelled sprayer, consumption rate, deviation from the consumption rate, height of spraying to the plants

Introduction

The chemical protection of plants from diseases and pests, as well as the control of weeds, is carried out by the introduction of pesticides using sprayers (Trendafilov, 2019). They are some of the most commonly used machines for control of diseases and pests in agricultural crops (Dragoev and Kazakova, 2016). The use of pesticides also carries the risk of a number of new problems arising, since biological control agents may be eliminated or pests may become resistant to the pesticide preparations used (Mitev, 2018). The correct selection and use of the correct sprayers is one of the most important steps in crop spraying (Shirwal et al., 2020). Deviation from the specified working solution consumption rate can be minimized by selecting the correct sprayer nozzles that dispense the largest droplet size while providing adequate coverage at the intended

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operating speed and operating pressure of the working solution (Safari and Kafashan, 2004). Other important characteristics in crop spraying affecting spraying efficiency are the spray angle, spray shape and distribution pattern of the solution volume (Minov et al., 2014). In spraying, atomizers do not atomize the liquid into droplets of uniform size and velocity, but into a set of droplets of different sizes and operating velocities (Lefebvre, 1989). It is important to quantify and control these distributions because they affect droplet trajectories (Butler Ellis et al., 1997). Spray nozzle characteristics are among the most critical factors affecting solution dispersion, deposition on plants, spray coverage, and biological efficacy. In this regard, some authors have investigated the effect of the type and size of the spray nozzle, the spray pressure on the spray droplet size (Nuyttens et al., 2007). Other authors have carried out a laboratory study by designing a sprayer to be operated and controlled remotely and to assess its performance at different operating travel speeds and at different pump operation pressure. In this way, according to them, the performance of the system when spraying the crop plants can be assessed and calibrated (Elwakeel et al., 2022).

Recently, unified sensors have started being installed on agricultural machines. In these the electronic unit, in addition to following and optimizing the working indicators and parameters, show the actual work speed of operation, the engine characteristics, the processed areas and diesel consumption (Mitev et al., 2019). According to some authors, a significant reduction of work costs has been established (Ivanishin et al., 2006). According to other authors, though, about 50% of the travel of the agricultural unit is saved, thus improving soil significantly (Chervet et al., 2007). A total of 27% of the agricultural farms had used automatic control systems, which additionally reduce the machine time by 5.75% and diesel consumption by 5.33% (Bora et al., 2012).

Improvement of efficiency in a given technological operation, incl. reduction of non-productive time and diesel consumption is done by planning the way of movement of the machine tractor unit (Trendafilov, 2018). Some authors have evaluated the spray system performance in both laboratory and field conditions in relation to solution spray loss (Dash et al., 2020). This is why precision farming systems automatically maintain the direction of movement based on accurate satellite positioning. The telematic system stores various data sets such as the machine's exact location, time stamp, idle time and the operator actions. Accordingly, the possibilities for data collection and analysis are promising (Oksanen et al., 2015; Van Hampton, 2015).

The objective of this paper is to analyse the main operational indicators and diesel fuel consumption of a self-propelled sprayer when spraying wheat and sunflower by using the *JD Link* telematics system.

Material and methods

The study was carried out in two fields as follows: field A with an area of 58.1 ha and field B with an area of 80.3 ha (Figures 1 and 2). Field A was sown with wheat of the *Renaissance* variety, while field B was sown with sunflower of the *NK Neoma* variety. The research was carried out with a John Deere 4730 self-propelled sprayer. The consumption rate for spraying the crops was the same for both fields of 150 l/ha.

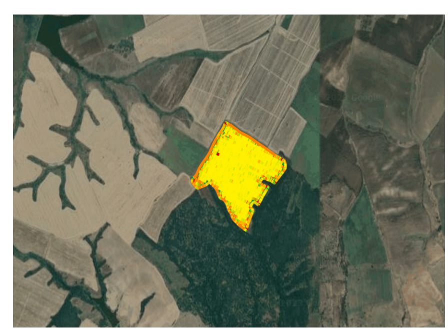


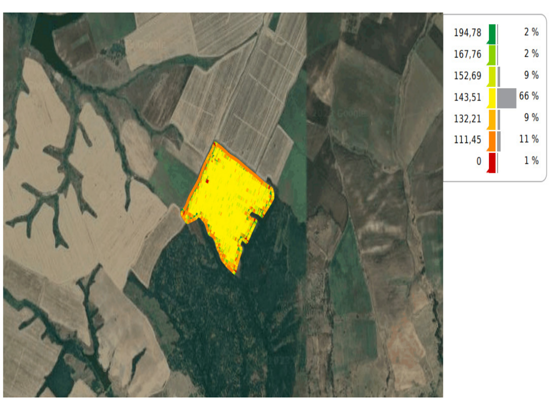
Figure 1. Map of field A - 58.1 ha

Figure 2. Map of field B - 80.3 ha

The study of field characteristics, agronomic data and performance indicators in crop spraying was made by using the *JD Link* telematics system. Data were downloaded from the system and imported and incorporated into a database.

Results and discussion

Figure 3 a) and b) shows the maps with the agronomic data for the two fields (A and B) when spraying the crops - wheat and sunflower. The analysis of the obtained data shows that 66% of the wheat spraying area in field A and 46% of the sunflower spraying area in field B were sprayed with a pre-set consumption rate of 150 l/ha. It is also evident that the deviation from the consumption rate in field A is 13%, and in field B 3% higher than the pre-set consumption rate (> 150 l/ha). It can be seen on Figure 3 a) and b) that the deviation from the consumption rate is 21% lower in field A and 6% lower in field B (< 150 l/ha).



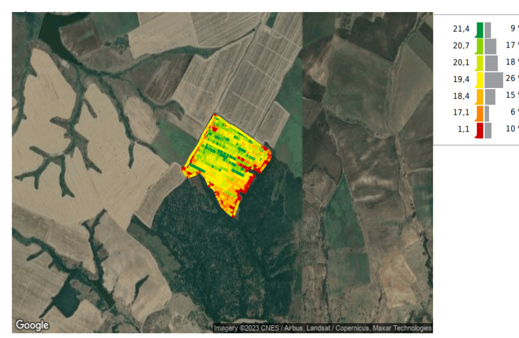
a

b

Figure 3. Consumption rate in spraying:

a) in field A; b) in field B

These differences can be explained by the results shown in Figure 4 a) and b) for the actual operating speed of the self-propelled sprayer. Based on the results for the actual operating speed of the self-propelled sprayer, it is observed that its pre-set operating speed is not maintained. This is due to the fact that in both fields yellow colouring predominates and in some places it can be seen that it even approaches the critical colour in orange (Figure 4 a) and b)). Not only maintaining a constant actual operating speed directly affects reaching the pre-set consumption rate of the working solution. In our case, either the correct spray nozzles were not selected for this operating speed, or the correct operating pressure of the working solution was not set. Since the operating speed is very variable, the controller cannot process the information received from the flow meter so quickly to adjust the pressure to the speed and orifice of the spray nozzles, and thus the consumption rate cannot be reached.



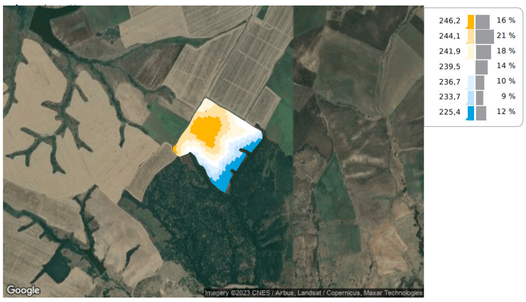
a

b

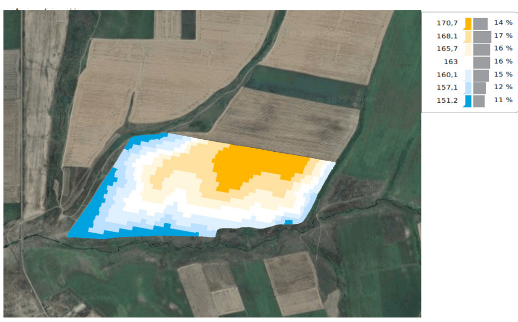
Figure 4. Actual operating speed in spraying:

a) in field A; b) in field B

The other important factor that is a prerequisite for speed is the flatness of the sprayed field. It can be seen on Figure 5 a) and b) that the field has an uneven terrain and that results in the uneven operating speed of the self-propelled sprayer. If the correct operating travel speed is not selected, the sprayer will suddenly slow down or increase speed, thus resulting in a "stressed" speed range.



a



b

Figure 5. Altitude:

a) in field A; b) in field B

Table 1 presents the results of the agronomic data and indicators of the consumption rate when spraying wheat in field A, which has an area of 58.1 ha. It shows that the actual applied consumption rate is 147.42 l/ha with an actual applied quantity of 8563.2 l. Based on this, it can be concluded that the size and shape of the field do not affect the consumption rate.

Table 2 presents the results of the agronomic data and indicators of the consumption rate when spraying sunflower in field B, which has an area of 80.3 ha. It shows that the actual applied consumption rate is 148.33 l/ha with an actual applied quantity of 11908.1 l.

Table 3 presents the results of the engine speed of the self-propelled sprayer in the three modes of operation. It can be seen from the table that the engine speed in a running engine are almost the same for both fields 2485.93 min^{-1} in field A and 2495.55 min^{-1} in field B. When the self-propelled sprayer was idling, its engine speed was as follows: when spraying the field with wheat 1481.42 min^{-1} and when spraying the field with sunflower they are 15% lower, i.e. 1253.83 min^{-1}. When the self-propelled sprayer moved along the road to the two fields, i.e. during transport its engine speed were 2405.55 min^{-1} to the wheat field (field A) and were 13% lower, i.e. 2091.09 min^{-1} as it moved to the sunflower field (field B). This difference can be explained by the actual operating speed.

Table 1. Applied and planned rate of products when spraying wheat on field A

Product	**Applied consumption rate** *l/ha*	**Totally applied** *l*	**Planned rate** *l/ha*	**Planned final quantity** *l*
Water	134.22	7796.5	136.57	7933
IMPULSE	1.97	114.2	2	116
WAN	9.83	570.9	10	581
INTESOL	0.98	57.1	1	58
GRANSTAR 75 DF	0.03	1.7	0.03	2
TECHNOFIT pH+	0.15	8.6	0.15	9
CYPERFOR	0.25	14.3	0.25	15
Total:	**147.42**	**8563.2**	**150**	**8713**

From the results presented in Table 3, the mean engine utilization factor of the self-propelled sprayer has been determined. It is evident from it that when the sprayer was performing the technological operation of spraying, i.e. it was fully operational, this coefficient when spraying wheat (field A) was 58.90% and when spraying sunflower (field B) it was 63.60%. The other relative shares are distributed as follows: 16.23% (field A) and 15.23% (field B) it was idling. Also, 54.46% (field A) and 39.86% (field B) it was in transport position.

Table 2. Applied and planned rate of products when spraying sunflower on field B

Product	Applied consumption rate *l/ha*	Totally applied *l*	Planned rate *l/ha*	Planned final quantity *l*
Water	146.18	11737.4	147.85	11871
CENTURION	1.98	158.8	2	161
TECHNOFIT pH+	0.15	11.9	0.15	12
Total:	**148.31**	**11908.1**	**150**	**12044**

Table 3. Engine speed and relative share of engine utilization of the self-propelled sprayer

Operational indicators	Measurements					
	idling		engine running		in transport position	
	Field A	Field B	Field A	Field B	Field A	Field B
Engine speed, *min*$^{-1}$	1481.42	1253.80	2485.93	2495.55	2405.55	2091.09
Relative share of engine utilization, %	16.23	15.23	58.90	63.60	54.46	39.86

Table 4 presents a summary of the results of measurements of diesel consumption when spraying in the two modes of operation of the self-propelled sprayer engine: idling and with the engine running. Based on the obtained results, we can summarize that the diesel consumed in field A is, respectively, 28.86% less than in field B. It is evident from Table 4 that the mean diesel consumption in field A is 7.27% less than in field B. On the one hand, this is due to the larger area of field B and, hence, the longer duration of spraying.

Table 4. Fuel consumption for crop spraying in various modes of engine operation

Operational indicators	Field A		Field B	
	idling	engine running	idling	engine running
Use of sprayer, *h*	0.57	1.34	1.09	1.75
Consumed quantity of diesel, *l*	4.26	44.51	6.61	62.56
Mean diesel consumption, *l/h*	7.50	33.18	5.87	35.78

Table 5. Operational characteristics and indicators for spraying

Operational characteristics	Field A	Field B
Area, *ha*	58.1	80.3
Working speed, *km/h*	19.2	19.1
Spraying time	*1 h 4 min*	*1 h 30 min*
Fuel, *l/ha*	0.6	0.7
Hourly productivity, *ha/h*	53.8	53
Total amount of fuel, *l*	36.3	54.7
Fuel consumption per hour, *l/h*	33.6	36.1

Table 5 presents the results about some operating characteristics and indicators when spraying the crops - wheat and sunflower. It is evident from the table that the actual operating speed of the self-propelled sprayer is almost the same an average of 19.1 km/h. It is also observed that the average hourly consumption of diesel fuel in field A is 7% less than in field B. This can be accounted for by the larger area of the field, and, hence, the longer duration of the technological operation spraying. However, the hourly productivity on both fields is less than 1% different. This is due, on the one hand, to the good qualification of the operator, and on the other hand, to the smaller idle runs when making the turns at the end of the field.

Conclusion

It has been established that: (i) 66% of the wheat spraying area in field A and 46% of the sunflower spraying area in field B were sprayed at the consumption rate set by the agronomist of 150 l/ha. (ii) It was established that either the correct sprayer nozzles have not been selected for the operating speed of the self-propelled sprayer or the correct operating pressure of the working solution has not been set. In this way, the controller cannot process the information received from the flow meter so quickly to adjust the pressure to the speed and oridice of the sprayer nozzles, and thus the consumption rate is not reached. (iii) From the presented results of the agronomic data and indicators for the consumption rate when spraying wheat in field A, it can be seen that the actual applied consumption rate is 147.42 l/ha with an actual applied quantity of 8563.2 l, and when spraying sunflower in a field B the actual applied consumption rate is 148.33 l/ha with an actual applied quantity of 11908.1 l. (iv) It has been established that the engine speed with the engine running were almost the same for both fields - 2485.93 min^{-1} in field A and 2495.55 min^{-1} in field B; in idle mode its engine speed were as follows: when spraying the wheat field 1481.42 min^{-1} and when spraying the sunflower field they were 15% lower, i.e. 1253.83 min-1. (v) The mean engine utilization coefficient of the self-propelled sprayer has been found. When the sprayer performed the technological operation of spraying, i.e. it was fully operational, this coefficient when spraying wheat (field A) was 58.90%, and when spraying sunflower (field B) it was 63.60%. The remaining relative shares are distributed as follows: 16.23% (field A) and 15.23% (field B) it was idling. Also, 54.46% (field A) and 39.86% (field B) it was in transport position. (vi) The consumption of the quantity of diesel used during spraying in the two modes of operation of the engine of the self-propelled sprayer has been determined: idling and with the engine running. From the obtained results, it can be summarized that the diesel consumed in field A is, respectively, 28.86% less than in field B, and the mean consumption of diesel fuel in field A is 7.27% less than in field B.

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