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Performance testing of field crop sprayers in the Rasina District

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Abstract: In agricultural production, pests and diseases of agricultural crops, as well as weed plants, cause significant losses in the yield and quality of agricultural products. One of the most effective ways of fighting is the use of a wide range of chemicals called pesticides. In accordance with the EU Directives 2009/128/EC and 2006/42/EC underlying the standard EN 13790, the Plant Protection Administration of the Ministry of Agriculture and the Environment of the Republic of Serbia has established a framework for the control of sprayers and mist blowers. Maintaining sprayers for pesticide application in a good state of repair and proper working order reduces their harmful effects on human health and the environment. The nozzle is one of the most important parts of plant protection machines, responsible for the following major functions: delivery of a given amount of liquid in a unit of time, dispersion of the liquid by making droplets of different sizes and forming a stream of a particular shape. Testing of the working safety of sprayers and nozzles was carried out in accordance with the European Standard EN 13790 which specifies the methods and equipment for inspection. The flow rate of nozzles was measured by an S001 nozzle tester (AAMS-Salvarani, Belgium). The measuring equipment used for testing the pesticide application device can accurately determine any deviation and irregularity in the application.

Keywords: measuring equipment, sprayers, pesticides, nozzles, plant protection.

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Introduction

In agricultural production, all agricultural crops are susceptible to harmful effects of plant diseases, pests and weed plants. For the control of harmful organisms, the most effective way for preventive protection against diseases, and for controlling pests and weeds is the chemical way. Contemporary agricultural production implies increasing use of pesticides as plant protection products, as well as the use of pesticide application machines (Urošević, 2001). The application of pesticides by sprayers is the most commonly used pesticide application process for crop protection because it is a cheap, effective and fast method (Višacki *et al.*, 2014b). The massive use of plant protection machines for the application of chemicals or pesticides has a major impact on the environment. High and careless use of pesticides can cause long-term adverse effects on soil fertility and quality. The basic task of mechanized protection to be fulfilled by tractor sprayers is to provide a uniform vertical distribution of the working fluid with precise dosing in individual zones for environmental reasons (Bugarin *et al.*, 2008). The performance of application machines treatment depends on proper functioning, adjustment and design, which affect the accuracy of pesticide distribution, the accuracy of dosage and the size of losses (Bugarin *et al.*, 2010; Srivastava, 2014). Inappropriate use of pesticides can cause harmful effects on operator, animals and the environment (Sedlar *et al.*, 2008; Sedlar *et al.*, 2014). The uniformity of spraying is affected by the method of disintegration of the working fluid. Distribution uniformity is described by the percentage coefficient of variation and is very important for the quality and efficiency of plant protection against diseases and pests as well as desiccation (Višacki *et al.*, 2014a). In plant protection, emphasis should be placed on the use of modern machines that provide controlled application of pesticides (Nikolić *et al.*, 2009).

Testing of plant protection machines in the European Union began in the late 1990s. In Germany, testing has shown that most defects in sprayers are caused by defective nozzles (Tadić *et al.*, 2014). In EU countries, regulations on the compulsory inspection of plant protection machines (with the 2009/128/EC and 2006/42/EC guidelines) have been established as the basis of standard EN 13790 (Banaj *et al.*, 2014; Đokić *et al.*, 2015; Đokić *et al.*, 2016; Barać *et al.*, 2017). The adopted laws comply with EU 91/414 EEC and relate to the mandatory control of sprayers and mist blowers (Koprivica *et al.*, 2015). The most important factors for plant protection machines are nozzles, which perform major functions such as delivery of a given amount of liquid in a unit of time. Nozzles disperse the liquid by creating droplets of an appropriate size, forming a stream of an appropriate shape (Banaj *et al.*, 2010; Bajkin *et al.*, 2014). Effective crop protection is possible only if uniform distribution of the working fluid on the treated surface, that is, the quality of pesticide application, is ensured. Richards *et al.* (1997) emphasized that the preferred coefficient of variation of the flow rate of nozzles is less than 10 %, and is acceptable up to 15%. Wang *et al.* (1995)

found that nozzles are in relatively good operation if the coefficient of variation is less than 10 % to 12 %. According to the criteria set by Višacki *et al.* (2013), if the coefficient of variation is less than 7 %, the working fluid distribution uniformity is exceptional. If this value is higher, ranging from 7 % to 9 %, uniformity is satisfactory. The coefficient of variation is tolerable up to 11 %; if it is higher, the uniformity of distribution is considered insufficient.

The aim of this study was to test sprayers and measure the flow of working fluid in several types of sprayers in order to determine their proper functioning, flow rate accuracy and flow uniformity of nozzles.

Material and methods

A field sprayer trial was conducted with farmers in the Rasina District in central Serbia. During the test, a control test for the proper functioning of nozzles was carried out, involving flow measurements and flow uniformity examination. Nozzle flow was measured by an SOO1 nozzle tester (AAMS-Salvarani, Belgium). The testing of five sprayers from different manufacturers (A, B, C, D, E) was done in three repetitions. The test pressure was 3 bars; the rpm PTO for tractors was 540 min^{-1} . Sprayer type A is manufactured by "Agromehanika", Kranj. The pump capacity of this sprayer is 60 l min^{-1} , and the volume of the liquid reservoir is 400 l. The B-type sprayer is a 400 liter rear mounted sprayer manufactured by "Fischer", Switzerland. Sprayers types C and E are manufactured by "Morava" Požarevac, tank capacity 330 l. Sprayer type D is made by "Agromehanika" Kranj, with a pump capacity of 60 l min^{-1} , and a 330 l liquid reservoir. The number of nozzles differed depending on the type and spray width of sprayer. It ranged from 16 nozzles (sprayers C, D, E), 19 nozzles (sprayer A), to 22 nozzles (sprayer B). The results were subjected to the analysis of the coefficient of variation. The technical specifications of the tested sprayers are shown in Table 1.

Table 1. Technical specifications of the tested sprayers

Parameters	Type of sprayers				
	A	B	C	D	E
Volume of tank (l)	400	400	330	330	330
Max. rpm PTO (min^{-1})	540	540	540	540	540
Required tractor power (kW)	>30	>30	>30	>30	>30
Aggregation mode	Rear mounted sprayer				
Number of nozzles	19	22	16	16	16
Work pressure (bar)	3	3	3	3	3
Treatment angle ($^{\circ}$)	80-110	80-110	80-110	80-110	80-110

Results and discussion

The results of testing the average flow rate of sprayers are shown in Table 2.

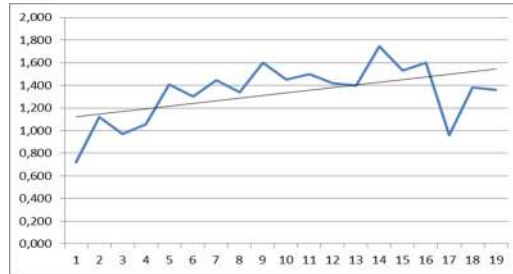
Table 2. The flow rate of crop sprayers

Number of nozzles	Flow rate of crop sprayers (l min ⁻¹)				
	Type of sprayers				
	A	B	C	D	E
1.	0.719	0.988	0.795	0.738	0.525
2.	1.118	1.003	1.055	0.742	1.349
3.	0.970	0.973	0.835	0.742	1.559
4.	1.058	0.978	1.007	0.746	1.472
5.	1.410	0.795	1.142	0.785	1.350
6.	1.304	0.887	1.022	1.108	1.575
7.	1.447	1.017	1.116	0.819	1.206
8.	1.337	0.799	1.225	0.844	1.584
9.	1.602	1.320	1.044	0.801	1.726
10.	1.451	1.243	0.824	0.812	1.573
11.	1.497	1.246	1.128	0.958	1.505
12.	1.418	1.214	0.916	0.586	1.492
13.	1.400	0.882	1.144	0.787	1.495
14.	1.747	0.946	1.142	0.760	1.586
15.	1.533	0.947	1.146	0.664	1.723
16.	1.599	0.905	1.174	0.712	0.422
17.	0.958	0.976	-	-	-
18.	1.379	0.862	-	-	-
19.	1.358	0.932	-	-	-
20.	-	0.883	-	-	-
21.	-	1.241	-	-	-
22.	-	1.062	-	-	-
Average	1.332	1.005	1.045	0.788	1.384
CV (%)	19.39	15.25	12.94	14.93	27.42

The results showed that the average flow rate of sprayers ranged from 0.788 l min⁻¹ (sprayer D) to 1.384 l min⁻¹ (sprayer E). The average flow rate of sprayers A, B and C was 1.332 l min⁻¹, 1.05 l min⁻¹ and 1.045 l min⁻¹, respectively. The coefficient of variation ranged from 12.94 % for Sprayer C to 27.42 % for sprayer E. Barać *et al.* (2017) reported that the average nozzle flow rate was 0.954 l min⁻¹, 1.169 l min⁻¹ and 1.190 l min⁻¹ (type C), with the coefficient of variation in the range of 12.24% to 29.49%.

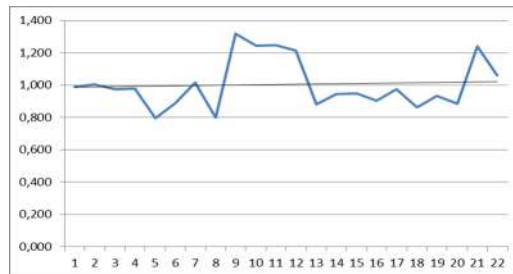
The average nozzle flow rates of the tested sprayers are shown in *Graphs 1-5*. For Sprayer A, the minimum average working fluid flow rate was 0.719 l min⁻¹ for nozzle 1, and the maximum rate of flow was 1.747 l min⁻¹ for nozzle 14. The average flow rate for sprayer A was 1.332 l min⁻¹ (Graph 1).

Graphic 1. Flow rate of crop sprayers ($l\ min^{-1}$) sprayer type A



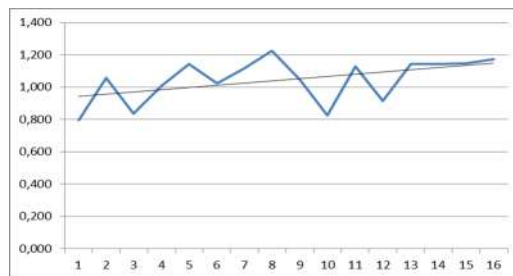
In sprayer B, the average flow rate ranged from $0.795\ l\ min^{-1}$ for nozzle 5 to $1.320\ l\ min^{-1}$ for nozzle 9. The average flow rate was $1.005\ l\ min^{-1}$ (Graph 2).

Graphic 2. Flow rate of crop sprayers ($l\ min^{-1}$) sprayer type B



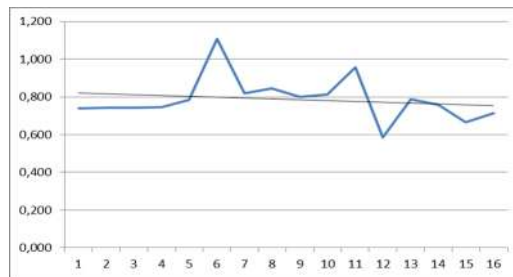
Sprayer C had a flow rate of $0.795\ l\ min^{-1}$ for nozzle 1 and $1.225\ l\ min^{-1}$ for nozzle 8. The average flow rate was $1.045\ l\ min^{-1}$ (Graph 3).

Graphic 3. Flow rate of crop sprayers ($l\ min^{-1}$) sprayer type C



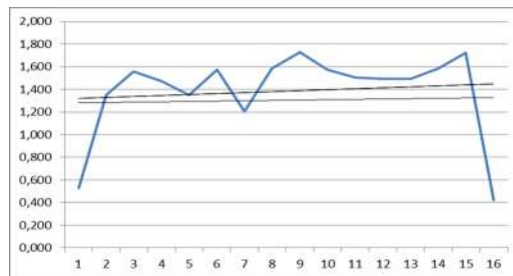
Sprayer D had a minimum flow rate of 0.586 l min^{-1} for nozzle 12, and a maximum of 1.108 l min^{-1} for nozzle 6. The average flow rate was 0.788 l min^{-1} (Graph 4).

Graphic 4. Flow rate of crop sprayers (l min^{-1}) sprayer type D

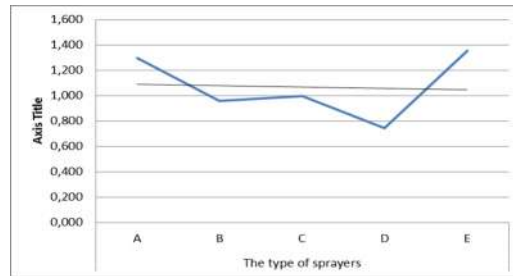


The flow rate of sprayer E ranged from 0.422 l min^{-1} for nozzle 16 to 1.726 l min^{-1} for nozzle 9. The average flow rate was 1.384 l min^{-1} (Graph 5).

Graphic 5. Flow rate of crop sprayers (l min^{-1}) sprayer type E



A comparative overview of the average flow rates of nozzles for all five sprayer types is given in Graph 6. The minimum average flow rate of 0.788 l min^{-1} was for D-type sprayer and a maximum of 1.384 l min^{-1} for sprayer E. Sprayers B and C had uniform values of average flow rates of operating fluid of 1.005 l min^{-1} and 1.045 l min^{-1} , respectively the average flow rate of type A sprayer was 1.332 l min^{-1} .

Graphic 6. Flow rate of crop sprayers ($l\ min^{-1}$) sprayer types A, B, C, D, E

The tested sprayer nozzles should be replaced as none of them meets the criteria regarding the coefficient of variation for the flow rate of nozzles set by Wang *et al.* (1995) and Višacki *et al.* (2013). According to Richards *et al.* (1997), only sprayer C nozzles are acceptable for further application. When the deviation from the nominal flow rate is above the specified limits, the working fluid distribution is usually incorrect and uneven, most often due to the clogging and damage of nozzle holes.

Conclusions

Defective nozzles on field sprayers are the biggest problem for the proper operation of plant protection machines. In the field, nozzles are often clogged due to mechanical impurities, poor water quality or deterioration due to prolonged exploitation time, which significantly affects the quality of pesticide application. In addition to regular maintenance and cleaning, it is necessary to perform regular inspection of the proper operation of nozzles on field sprayers and mist blowers. The working fluid flow rate depends on nozzle condition; pump condition and sprayer maintenance method. The average flow rates of the tested sprayers ranged from a minimum of $0.788\ l\ min^{-1}$ (sprayer D) to a maximum of $1.384\ l\ min^{-1}$ for sprayer E. In sprayers A, B and C, the average operating fluid flow rate was $1.332\ l\ min^{-1}$, $1.005\ l\ min^{-1}$ and $1.045\ l\ min^{-1}$, respectively the coefficient of variation ranged from 12.94 % (sprayer C) to 27.42 % (sprayer E). Such a large deviation in the average values of the fluid flow rate is due to nozzle deterioration or blockage; therefore, they need to be cleaned and, if necessary, replaced with new ones.

Acknowledgement

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ISPITIVANJE KARAKTERISTIKA RATARSKIH PRSKALICA U RASINSKOM OKRUGU

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Rezime

U poljoprivrednoj proizvodnji, štetočine i bolesti poljoprivrednih kultura, kao i korovske biljke svake godine prouzrokuju značajne gubitke u prinosu i kvalitetu poljoprivrednih proizvoda. Jedan od najefikasnijih načina borbe jeste primena brojnih i različitih hemijskih sredstava, koja se nazivaju opštim nazivom pesticidi. U skladu sa Direktivama Evropskog parlamenta 2009/128/EC i 2006/42/EC, kojima je osnova standard EN 13790, koji propisuje obavezni pregled mašina za zaštitu bilja, Uprava za zaštitu bilja Ministarstva poljoprivrede i životne sredine Republike Srbije uspostavlja okvir za kontrolu sistema prskalica i orošivača. Upotrebom tehnički ispravnih i kontrolisanih ratarskih prskalica za primenu pesticida smanjuje se njihov štetni uticaj na zdravlje ljudi i životnu okolinu. Jedan od najznačajnijih delova mašina za zaštitu bilja predstavljaju rasprskivači. Oni obavljaju najvažnije funkcije, kao što su: propuštaju zadate količine tečnosti u jedinici vremena, raspršuju tečnost praveći kapljice odgovarajućih veličina i formiraju mlaz odgovarajućeg oblika. Testiranje radne ispravnosti prskalice i rasprskivača vršeno je u skladu sa evropskim normativom EN 13790, koji propisuje metode i opremu kojom se obavlja inspekcija. Protok rasprskivača je meren pomoću ispitivača pojedinačnih rasprskivača S001 belgijskog proizvođača "AAMS-Salvarani". Primenom merne opreme za ispitivanje ispravnosti rada uređaja za primenu pesticida, merenjem je moguće tačno ustanoviti svako odstupanje i nepravilnost u radu. Dobijeni rezultati ukazuju na to da postoje značajna odstupanja ispitivanih parametara.

Ključne reči: merna oprema, prskalice, pesticidi, rasprskivači, zaštita bilja.