CHANGES OF COEFFICIENT OF VARIATION OF TRANSVERSE LIQUID DISTRIBUTION FOR SINGLE AND DUAL STREAM ATOMIZERS

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Abstract. The aim of the study was to clarify the influence of the height, the setup of an angle of the boom sprayer and the pressure of liquid on the value of the coefficient of variation of the transverse liquid distribution. Single XR 11003 VP and dual TJ 6011006 VS stream atomizers were used in the study. Nozzle spacing on the boom sprayer was 0.5 meters. The average temperature of water used to this test was14 ºC. The measurement of the coefficient of variation of the transverse liquid distribution was performed using an automatic groove table Hardi Spray Scanner with groove resolution of 100 mm. The final result was expressed by the coefficient of variation of the transverse liquid distribution according to ISO 5682-3. Regardless of the use of the single or dual stream atomizers the strongest impact on the value of the coefficient of variation of the transverse liquid distribution had the height of the boom sprayer, then the angle of the boom setup and the smallest the pressure of the liquid. Regardless of the combination of the analyzed variables the use of the dual stream atomizers results in a reduction of the coefficient of variation of the transverse liquid distribution in relation to the use of the single stream atomizers. Deflection of the boom sprayer at the angle of 5 degrees significantly increases the value of the coefficient of variation of the transverse liquid distribution. For the single and dual stream atomizers they were 8.56 % and 9.07 %, respectively.

Keywords: boom sprayer, liquid distribution, single and dual stream atomizers.

Introduction

The development of the plant protection technology makes the placing on the market newer and newer technical solutions in order to reduce the use of pesticides and improve the efficiency of their actions. To take the full advantages of the available technique, it must be combined with rational performing the procedure, which results from the consciousness of the sprayer operator. The use of new solutions must be preceded by studies that demonstrate the benefits and dangers for the environment. One of such solutions is to use dual stream nozzles. These elements have a great influence on the quality of application from the view of devices for pesticide application. Using the appropriate nozzles gives the required amount of liquid pesticide on the plant surface. The characteristic of the nozzle work allows to reduce the excessive application of liquid to the upper zones of the plants and increases the liquid application on the vertical bottom parts [1-3].

To the advantages of these nozzles may be included the possibility of increasing the working speed while maintaining the required degree of coverage on the sprayed surfaces [4]. The important factor that describes the quality of application is the value of the coefficient of variation. That coefficient depends on the working pressure of pumping application and the way of disintegration of the liquid that flows through the nozzles [5]. However, during working the working parameters may be changed due to the impact of the field conditions. Uncontrolled tilts of the boom sprayer and changes of the working height will cause: increase in the value of the inequality coefficient of spraying, excessive drift of liquid and ecological threats to neighboring crops [6-10]. The effectiveness of treatment in these conditions can be limited and depends largely on the uniformity of the liquid precipitation on the sprayed surfaces and on the degree of coverage [4; 11-13].

Therefore, the aim of the study was to clarify the influence of the height, the setup of an angle of the boom sprayer and the pressure of liquid on the values of the coefficient of variation of the transverse liquid distribution for the boom sprayer equipped with single and double-stream atomizers.

Materials and methods

Measurements of spraying inequality were carried out in the laboratory conditions. The field sprayer pump was driven by an electric motor through a continuously variable transmission. Fixing the boom sprayer allowed to a smooth change in its height and angle settings. Controlling the flow of liquid was carried out using a constant pressure control valve with pressure compensation for each section. Single XR11003-VP and dual TJ 60 110 06 VS stream atomizers were used in the study. The nozzles were mounted on the five positional heads on a four meter section of the boom sprayer. The nozzle spacing on the boom sprayer was 0.5 meter. The average temperature of water used to this test was 14 ºC. The measurement of the coefficient of variation of the transverse liquid distribution was performed using an automatic groove table - Hardi Spray Scanner with groove resolution of 100 mm [14]. During the test, the device was automatically moved on the aluminum rails, measuring the liquid distribution for the successive segments of the boom sprayer. Supporting program calculated the instantaneous measurements giving the final result expressed by the coefficient of variation of the transverse liquid distribution according to ISO 5682-3 [15]:

$$CV = \frac{\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(V_i - V_{śr}\right)^2}}{V_{śr}} 100$$

where CV – coefficient of variation of the transverse liquid distribution, %;
n – numbers of measuring grooves on the grooved table within the liquid stream obtained from the atomizers,
V_i – liquid volume collected from the i-th groove of the measuring table, m^3;
$V_{śr}$ – average volume of liquid from the single groove of the measuring table, m^3.

In the course of the study the variable parameters were: working pressure, slope and height of the boom sprayer over the measuring table. Changes of the liquid pressure were carried out in the range from 0.2 to 0.4 MPa, every 0.05 MPa with an accuracy of 0.01 MPa. The slope of the boom sprayer was varied from 0 to 5 degrees every 1 degree with an accuracy of 0.1 degree. The range of the heights of the boom sprayer over the measuring table was from 0.4 to 0.6 m, every 0.1 m with accuracy of 0,005. The layout of variables was repeated for both boom sprayers with single and dual stream atomizers. For each combination of variables the measurements were repeated three times.

Results and discussion

The research results were statistically analyzed in order to verify the significance of differentiation of the values of the coefficient of variation of the transverse liquid distribution in each measuring system for the tested single and dual stream atomizers. The analysis also included two and three factor interactions between the tested parameters. For all of the main factors and four pairs of interactions between them, the analysis of variation showed statistically significant differentiation at $\alpha = 0.05$ level (Table 1).

Table 1

Analysis of variance of the factors influencing the coefficient of variation of the transverse liquid distribution for the boom sprayer with single and dual stream atomizers

Source	Sum of squares	Degrees of freedom	Mean square	*F*-test	*P*-value
Single XR 11003 VP stream atomizer					
Parameter					
Height: h	491.13	2	245.56	2546.9	<0.0001
Angle: k	362.18	5	72.44	751.3	<0.0001
Pressure: p	23.12	4	5.78	60.0	<0.0001
Interactions					
h × k	589.72	10	58.97	611.6	<0.0001
h × p	12.35	8	1.54	16.0	<0.0001
k × p	13.48	20	0.67	7.0	<0.0001
h × k × p	21.22	40	0.53	5.5	<0.0001
Dual TJ 6011006 VS stream atomizer					
Parameter					
Height: h	343.47	2	171.73	2083.7	<0.0001
Angle: k	650.88	5	130.17	1579.4	<0.0001
Pressure: p	62.475	4	15.619	189.51	<0.0001

Table 1 (continued)

Source	Sum of squares	Degrees of freedom	Mean square	*F*-test	*P*-value
Interactions					
h × k	922.70	10	92.270	1119.5	<0.0001
h × p	49.166	8	6.1458	74.57	<0.0001
k × p	48.492	20	2.4246	29.42	<0.0001
h × k × p	14.835	40	0.6211	7.54	<0.0001

For two variants of the used atomizers the decrease in the values of the coefficient of variation of the transverse liquid distribution along with increasing the height of the boom sprayer setup were observed (Fig. 1). It could be stated that independently from the changes in the liquid pressure and setup of the boom sprayer angle, the higher values for the single stream atomizer were observed. For the single stream atomizers the highest value for the height of the boom sprayer of 0.4 m was observed and it was 8.69 %.

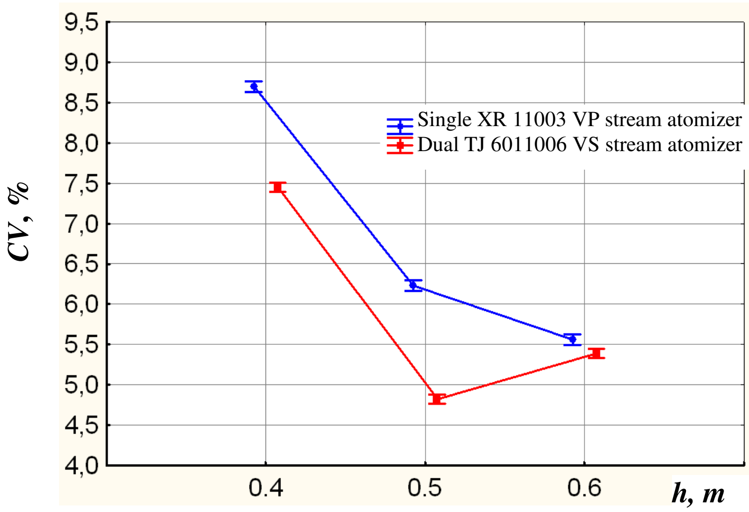

Fig. 1. **Changes in the values of the coefficient of variation of the transverse liquid distribution for the boom sprayer with single and dual stream atomizers depending on the height setting of the boom sprayer**

Increase in the height of the boom sprayer by 0.2 m caused decrease in the coefficient of variation value by 3.11 %. For the dual stream atomizer, the highest value of that coefficient was observed for the lowest tested height of the boom sprayer (0.4 m) also and it was 7.45 %. For this atomizer increase in the height of the boom sprayer caused decrease in the coefficient of variation value, however, the lowest value was observed for 0.5 m height and it was 4.82 %. Further increase in the height of the boom sprayer to 0.6 m height caused slight increase in the coefficient of variation to 5.39 %. Lower values of the coefficient of variation of the transverse liquid distribution for higher working heights are the result of a greater coverage of the range for spray in such an operating system. This is particularly evident for double stream atomizers, where we have double spray streams, hence the more favorable values for this type of sprayers.

The change of the angle of the boom setup in the range from 0º to 5º, independently from the changes of the pressure of the liquid and height of the boom sprayer, for single and dual stream atomizers caused increase in the values of the coefficient of variation of the transverse liquid distribution (Fig. 2). Higher values were observed for single stream atomizers, and they were 5.19 % for horizontally positioned boom and increased to 8.56 % for the angle of 5º. Average change per unit of the coefficient of variation was 0.67 % for 1° of boom tilting. The boom sprayer with dual stream atomizers was characterized by lower values of the coefficient and in the range of 0–4° they were from 4.61 % to 6.36 %, respectively.

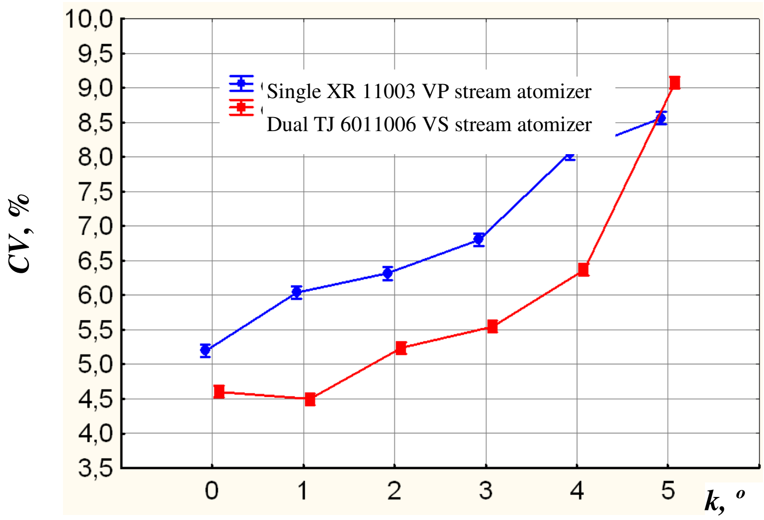

Fig. 2. **Changes in the values of the coefficient of variation of the transverse liquid distribution for teh boom sprayer with single and dual stream atomizers depending on the angle setting of the boom sprayer**

However, for the boom sprayer tilting at 5° this coefficient had the highest value and it was 9.07 %. Hence, the average change of the coefficient of variation per unit for boom sprayer with dual stream atomizers was 0.89 % for every 1° of boom tilting. Inclination of the boom relative to the ground worsens the spraying conditions. The observed situation is the result of overlapping the spraying fans in the part of the boom that is high over the measuring table during inclination. Simultaneously, there is no cover of spraying fans in the part of the boom when it is low over the table. In extreme cases a zone can occur, in which a non sprayed strip of crops remains. For dual stream atomizers it is less visible because of double streams. However, at high angle of the boom setup – the change from 4° to 5°, the coefficient of variation increased by 2.71 %. It is involved with dispersion of liquid high above the spraying surface and thus worsens the variation.

The changes of the pressure of the liquid, independently from the changes of the height and angle of the boom sprayer, slightly affected the values of the coefficient of variation of the transverse liquid distribution (Fig. 3).

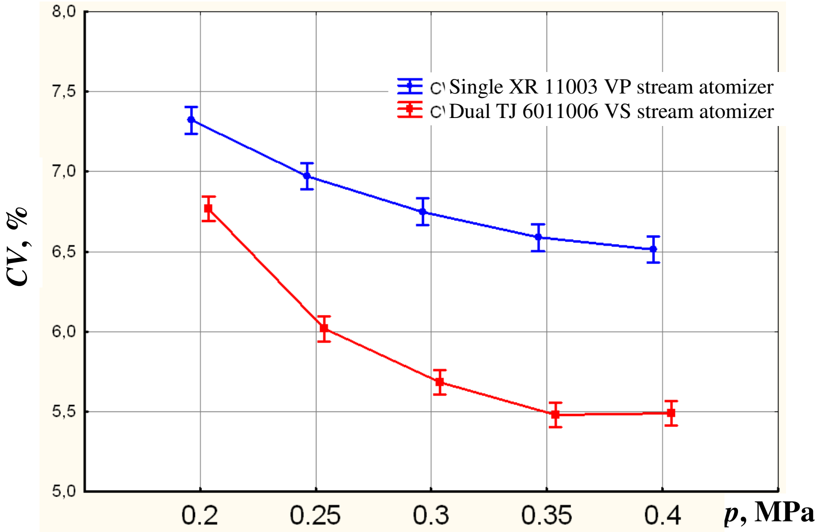

Fig. 3. **Changes in the values of the coefficient of variation of the transverse liquid distribution for the boom sprayer with single and dual stream atomizers depending on the working pressure of the liquid**

In the tested range of pressures of the liquid from 0.2 to 0.4 MPa, the values of the coefficient of variation have changed for the boom sprayer equipped with single stream atomizers from 7.32 % to 6.51 % (means by 0.81 %) and for dual stream atomizers the change was in the range from 6.77 to

5.48 % (1.29 %). The boom sprayer with dual stream atomizers was characterized by lower values of the coefficient of variation, an average of 0.94 % for the same pressures of the liquid compared to the boom sprayer with single stream atomizers. Independently from the used atomizers, the increase of the pressure of the liquid caused improvement of the spraying quality, mean lower values of the coefficient of variation of the transverse liquid distribution.

Conclusions

1. Regardless of the used single and dual stream atomizers, the highest impact on the coefficient of variation of the transverse liquid distribution had the height of the boom sprayer, then the angle of the boom setup and the smallest the pressure of the liquid.
2. Regardless of the analyzed combination of variables, the use of the dual stream atomizers results in a reduction of the coefficient of variation of the transverse liquid distribution in the relation to the use of the single stream atomizers.
3. Deflection of the boom sprayer at an angle of 5 degrees significantly increases the value of the coefficient of variation of the transverse liquid distribution, what was clearly noticed for the boom sprayer with dual stream atomizers.

References

1. Maertens W., Nuyttens D. and Sonck B., 2005. Optimization of sequence and orientation for used nozzles based on few, full boom distribution measurements. In Agricultural and Applied Biological Sciences, Ghent University, 70(40).
2. Lardoux Y., Sinfort C., Enfält P. and Sevila F., 2007, Test method for Boom Suspension Influence on spray distribution, Part I: Experimental study of Pesticide Application under a moving boom. Biosystems Engineering, 96(1), pp. 29-39.
3. Szewczyk A., Łuczycka D., Lejman K. 2011: Wpływ parametrów opryskiwania wybranym rozpylaczem dwustrumieniowym na stopień pokrycia opryskiwanych obiektów. (The impact of spraying parameters of chosen dual stream atomizer on the cover degree of spraying objects). Inżynieria Rolnicza 4(129): pp. 265-271 (in Polish).
4. Szewczyk A., Łuczycka D. 2011: Ocena stopnia pokrycia opryskiwanych powierzchni asymetrycznym rozpylaczem dwustrumieniowym. (The assesment of cover degree of surfaces sprayed by assymetric dual stream atomizer). Inżynieria Rolnicza 9(134): pp. 247-254 (in Polish).
5. Al-Gaadi K. A. 2010: Effect of nozzle height and type on spray density and distribution for a ground field sprayer. J. Saudi Soc. for Agric. Sci., 9(1): pp. 1-12.
6. Nowakowski T. 2004: Wpływ parametrów technicznych opryskiwacza na jakość oprysku. (Influence of technical parameters of the sprayer on the spraying quality). Technika Rolnicza Ogrodnicza Leśna 9-10: pp. 59-61 (in Polish).
7. Nowakowski T. 2006: Model empiryczny współczynnika zmienności poprzecznej oprysku w zależności od parametrów technicznych opryskiwacza. (The empirical model of the coefficient of variation of the transvrse liquid distribution according to the technical parameters of sprayer). Zeszyty Problemowe Postępów Nauk Rolniczych 508: pp. 125-130 (in Polish).
8. Nowakowski T. 2007: Selected technical parameters influencing the quality of spraying. Annals of Warsaw Agricultural University – SGGW, Agriculture No. 50, Agricultural Engineering: pp. 33-38.
9. Nuyttens D., Baetens K., De Schampheleire M., Sonck B. 2007. Effect of nozzle type, size and pressure on droplet characteristics. Biosystems Eng. 97(3): pp. 333-345.
10. Nuyttens D., De Schampheleire M., Verboven P., Brusselman E., Dekeyser D. 2009: Droplet size and velocity characteristics of agricultural sprays. Transactions of the ASABE 52 (5): pp. 1471-1480.
11. Lipiński A., Choszcz D., Konopka S. 2007a: Ocena rozpylaczy do oprysku ziemnia-ków w aspekcie równomierności pokrycia roślin cieczą. (The assesment of atomizers for potatoes spraying in the aspect of uniformity of coverage plants by liquid). Inżynieria Rolnicza 9(97): pp. 135-141 (in Polish).

12. Lipiński A., Choszcz D., Konopka S. 2007b: Rozkład poprzeczny cieczy dla rozpy-laczy Syngenta potato nozzle. (Transverse liquid ditribution for Syngenta nozzles). Inżynieria Rolnicza 9(97): pp. 143-148 (in Polish).
13. Łuczycka D., Szewczyk A., Cieniawska B. 2014: Charakterystyka opryskowa ro-ślin jako przydatne kryterium doboru rozpylaczy do zabiegu. (The spraying characteristic of crops as an usefull criterion of atomizers choice). Zeszyty Problemowe Postępów Nauk Rolniczych 577: pp. 93-102 (in Polish).
14. Miszczak M. 2000: Elektroniczny stół rowkowy HARDI SPRAY SCANNER. (The electronic groove table - HARDI SPRAY SCANNER). Przegląd Techniki Rolniczej i Leśnej 1: pp. 14-15 (in Polish).
15. ISO 5682-3 1997: Equipment for crop protection – Spraying equipment - Part 3: Test methods for volume/hectare adjustment systems of agricultural hydraulic pressure sprayers.