Katarzyna DEREŃ[1], Beata CIENIAWSKA[1], Antoni SZEWCZYK[1], Tomasz R. SEKUTOWSKI[2], Zbyszek ZBYTEK[3]
[1] Wroclaw University of Environmental and Life Sciences, Institute of Agricultural Engineering
ul. Chełmońskiego 37A, 51-630 Wrocław, Poland
e-mail: katarzynaderen@gmail.com
[2] Institute of Soil Science and Plant Cultivation - National Research Institute, Puławy,
Department of Weed Science and Tillage Systems, ul. Orzechowa 61, 50-540 Wrocław, Poland
e-mail: tomset2@wp.pl
[3] Industrial Institute of Agricultural Engineering, ul. Starołęcka 31, 60-963 Poznań, Poland

Received: 2017-04-25 ; Accepted: 2017-05-29

AVERAGE LIQUID COVERAGE DEPENDING ON THE TYPE OF THE NOZZLE, SPRAYING PARAMETERS AND CHARACTERISTICS OF THE SPRAYED OBJECTS

Summary

The research has been carried out in laboratory conditions at the Institute of Agricultural Engineering at Wroclaw University of Environmental and Life Sciences. Two single- and two-stream ejector nozzles were used for the tests, which operated at the pressure of 0.2 and 0.4 MPa. The water sensitive papers placed on artificial plants were the sprayed objects. During tests, the sprayer moved at a constant operating speed of 8 km·h^{-1}. The degree of coverage was determined by means of a computer image analysis in the Adobe Photoshop 7.0 CE program. The purpose of the research was to determine the average degree of coverage of the sprayed objects depending on the type and operating conditions of the nozzles and the spray characteristics. It has been shown that the spraying characteristic of the plants has an influence on the average coverage of the sprayed objects and it facilitates the selection of the right type of the nozzle for spraying the plants. This helps reduce the use of plant protection products, thereby reducing the pollution of the environment and surface waters with harmful substances.
Key words: *spray surface coefficient, plant protection, nozzle, spraying*

ŚREDNIE POKRYCIE CIECZĄ W ZALEŻNOŚCI OD RODZAJU ROZPYLACZA, PARAMETRÓW ROZPYLANIA I CHARAKTERYSTYKI OPRYSKIWANYCH OBIEKTÓW

Streszczenie

Badania wykonano w warunkach laboratoryjnych w Instytucie Inżynierii Rolniczej na Uniwersytecie Przyrodniczym we Wrocławiu. Do badań wykorzystano dwa rozpylacze eżektorowe jedno i dwu strumieniowe, które pracowały przy ciśnieniu 0,2 oraz 0,4 MPa. Opryskiwanymi obiektami były papierki wodnoczułe umieszczane na sztucznych roślinach. Opryskiwacz podczas badań poruszał się za stałą prędkością roboczą wynoszącą 8 km·h^{-1}. Stopień pokrycia określano przy pomocy komputerowej analizy obrazu w programie Adobe Photoshop 7.0 CE. Celem wykonanych badań było określenie średniego stopnia pokrycia opryskiwanych obiektów w zależności od rodzaju i warunków pracy rozpylaczy oraz charakterystyki opryskowej. Wykazano, że charakterystyka opryskowa roślin ma wpływ na średnie pokrycie opryskiwanych obiektów oraz ułatwia dobór właściwego rodzaju rozpylacza do wykonania zabiegu opryskiwania roślin. Pozwala to ograniczyć zużycie środków ochrony roślin, a dzięki temu zmniejszyć skażenie środowiska oraz wód powierzchniowych szkodliwymi substancjami.
Słowa kluczowe: *współczynnik powierzchni opryskowych, ochrona roślin, rozpylacz, opryskiwanie*

1. Introduction

The biological effectiveness of the plant protection products (p.p.p.) is largely dependent on the quality of the plant protection treatment performed. The quality of spraying is determined, among others, by the following indicators:
- degree of coverage of the sprayed areas (expressed in %),
- application of the utility liquid – mass – (µg) per 1 cm^2 of the surface,
- drops per 1 cm^2 of the plant [5].

The effectiveness of the application of p.p.p., and consequently their biological effectiveness and the amount of active substance remaining in the environment after spraying, depends on the quality of preparation used for spraying [4]. Spraying is defined by the category of drop rate, which is an important operating micro-parameter of the nozzle, which corresponds to the quality of coverage of the sprayed objects [2].

By knowing the spraying characteristics of the plants, which is described to the sprayed surface ratio determining the relation of the vertical to horizontal surfaces of the tested plant, we can select the appropriate type of the nozzle to the size of the sprayed plants (depending on, e.g., their developmental phase) [12, 13].

It should be remembered that for the spraying of plants to be effective, we must pay attention not only to a type of nozzle which is used to perform it, to a dose of the utility liquid and preparation is used for the given crop, but also to a selection of the appropriate nozzle for the procedure. The nozzle's function is to apply the required amount of active substance to the object with minimizing its losses in the environment. Unfortunately, many farmers often obtain the expected efficiency of the applied p.p.p. through their overdose, thus compensating for the poor technical condition of the spraying equipment and other causes of the non-uniform application of the utility liquid on the sprayed plant surfaces [2].

If too much p.p.p. is applied on the plant, this will cause permanent damage to the plant tissue – so both the appropriate amount of the applied agent and the quality of the equipment used for the procedure are important. Currently, the chemical plant protection in many European countries, also in Poland, is widely used, unfortunately more often in order to prevent than to control. The intense usage of p.p.p. leads to the appearance of pesticide residues in the plants. The European Union law does not allow for the raw materials intended for food processing to contain the residues of p.p.p.

One of the ways to reduce the consumption of chemical resources consists in the selection of the appropriate type of sprayer for the treatment, that is why the tests were performed at the Institute of Agricultural Engineering at the University of Life Sciences in Wroclaw, whose results facilitate the selection of the best type of nozzle depending on the spraying characteristics of the plant. The purpose of the research was to determine the average coverage of the sprayed objects depending on the type and operating conditions of the nozzles, as well as the spraying characteristics of the plants. It was attempted to show that the morphological structure of the plant, the arrangement of the leaves and stems in relation to the nozzle has a significant influence on the results of the process of covering the plants with the utility liquid.

2. Material and methods

The research was conducted in the laboratory conditions at the Institute of Agricultural Engineering at the Wroclaw University of Environmental and Life Sciences. The following spraying parameters were used for the tests: pressure 0.2 and 0.4 MPa, constant working speed 8 $km \cdot h^{-1}$, ejector nozzles – two-stream GAT 110-02 and one-stream FCGA 110-02, and the height of nozzles 0.5 m from the sprayed objects.

The coverage degree studies were performed using a self-propelled sprayer carrier, which is shown in Fig. 1.

The sprayer was moving on a specific track consisting of three parts: the runway section, the measuring section and the final section, where it has lost its operating speed. Three artificial plants were set up on the measuring section, which were the consecutive repeats. Testers in the form of water sensitive papers were placed on the artificial plants. Testers were fixed to the vertical surfaces (approach, depart, left and right, and the horizontal surfaces (top and bottom) of the artificial plants. The liquid coverage of the bottom horizontal surfaces was not observed during studies.

The coverage degree was determined by the computer image analysis method. First, hydrophilic papers were digitized using a scanner. Then, the testers were processed in the Adobe Photoshop 7.0 CE graphics program. Three randomly selected fragments with the area of 10x10 mm were marked on each tester, and the size of the sprayed area was read [3]. The degree of coverage was calculated using formula 1:

$$P_{sp} = \frac{W_k}{W_p} = \cdot 100\% \qquad (1)$$

where:
P_{sp} – degree of coverage [%],
W_K – surface covered with liquid [pixels],
W_p – the total test area equals to 1 cm^2 [pixels].

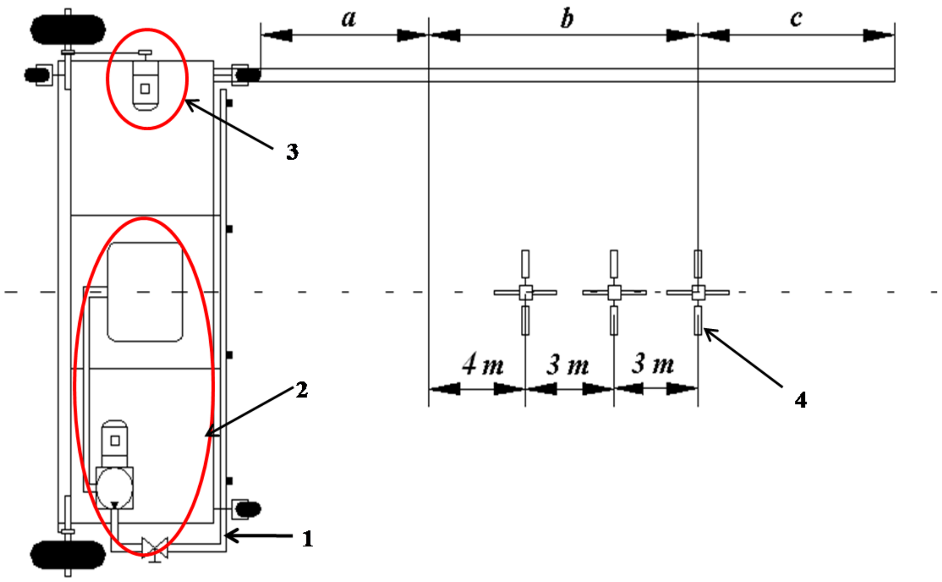
The spray surface coefficient was calculated from the product of the vertical and horizontal planes in accordance to formula 2:

$$W_{po} = \frac{surface \cdot vertical \cdot projections}{surface \cdot horizontal \cdot projections} \qquad (2)$$

where:
W_{po} – coefficient of spray surfaces [-].

The following coefficients of spray surfaces W_{po} were used for the studies: 0.25; 0.50; 0.75; 1.0; 1.25; 1.50; 1.75; 2.0.

In Table 1 gives the surfaces of the horizontal and vertical projections for the adopted values of the spray surface coefficients, of an exemplary plant with the surface of 100 cm^2.



Source: own work / Źródło: opracowanie własne

Fig. 1. The research station layout: a – runway section, b – measuring section, c – final section, 1 – sprayer carrier, 2 – liquid system of the sprayer carrier, 3 – propulsion system of the sprayer carrier, 4 – artificial plant

Rys. 1. Schemat stanowiska badawczego: a – odcinek rozbiegowy, b – odcinek pomiarowy, c – odcinek końcowy, 1 – nośnik rozpylaczy, 2 – układ cieczowy nośnika rozpylaczy, 3 – układ napędowy nośnika rozpylaczy, 4 – sztuczna roślina

Table 1. The total surface of horizontal and vertical projections of the plants for the assumed coefficients of spray surfaces
Tab. 1. Sumaryczna powierzchnia rzutów poziomych i pionowych roślin dla przyjętych współczynników powierzchni opryskowych

W_{po}	Horizontal surfaces (a) [cm^2]		Vertical surfaces (b) [cm^2]			
			transverse		longitudinal	
	top	bottom	approach	depart	right	left
0.25	40.00	40.00	5.00	5.00	5.00	5.00
0.5	33.335	33.33	8.33	8.33	8.33	8.33
0.75	28.57	28.57	10.71	10.71	10.71	10.71
1.0	25.00	25.00	12.50	12.50	12.50	12.50
1.25	22.22	22.22	13.89	13.89	13.89	13.89
1.5	20.00	20.00	15.00	15.00	15.00	15.00
1.75	18.18	18.18	15.91	15.91	15.91	15.91
2.0	16.66	16.66	16.66	16.66	16.66	16.66

Source: own work / Źródło: opracowanie własne

After calculating the degree of coverage (P_{sp}) for each sprayed area and the selection of the coefficient of the spray surface (W_{po}). the calculations of the theoretical degree of coverage (P_t) were performed according to formula 3. The theoretical degree of coverage (P_t) was calculated separately for the vertical surfaces (approach, depart, right and left) and for the horizontal surfaces (top and bottom).

$$P_t = 0{,}01 \cdot P_{sp} \cdot W_t \qquad (3)$$

where:
P_t – degree of coverage for the theoretically existing plant with the surface of 100 cm^2 [cm^2],
P_s– degree of coverage calculated separately for all sprayed vertical and horizontal surfaces [%],
W_t – theoretical surface of the tester corresponding to the given W_{po} for the plant with the surface of 100 cm^2 (the values are given in tab.1) [cm^2].

The degree of coverage (P_t) for the theoretically existing plant was calculated separately for both tested nozzles and two different pressures. Examples of the results of the theoretical degree of coverage (P_t) for the GAT 110-02 nozzle and pressure 0.4 MPa are presented in Tab. 2.

After obtaining the results of the theoretical degree of coverage (P_t), the average degree of coverage (P_{ss}) was calculated for all studied surfaces (horizontal and vertical) for individually assumed coefficients of the spray surfaces (W_{po}). The average degree of coverage (P_{ss}) was calculated by summing the values of the coverage (P_{sp}) of the tested horizontal and vertical surfaces, and then the resulting value was divided by their amount.

Example results of the average degree of coverage (P_{ss}) for the GAT 110-02 nozzle and pressure 0.4 MPa are presented in Tab. 2.

3. Results and discussion

Results of the studies on the average degree of coverage (P_{ss}) of the sprayed testers are shown in Fig. 2-3.

The analysis of the graphs presented in Fig. 2-3 shows that the single-stream nozzle FCGA 110-02 is characterised by a greater variability of the average coverage compared to the double-stream nozzle GAT 110-02 regardless of the pressure, with which the spraying was done. Similar observations were noticed by Łuczycka et al. [12] and Łuczycka et al. [13] in her publications, which stated that the single-stream nozzles have a better coverage of the sprayed surfaces than the double-stream nozzles.

When the sprayed object was characterised by W_{po}=2 (this means that the plant has more vertical surfaces, e.g. monocotyledonous plants), then the FCGA nozzle at the pressure of 0.2 MPa was characterised by a lower average degree of coverage, while with a change in coefficient to W_{po}=0.5 (a smaller amount of horizontal surfaces in the plant, e.g. dicotyledonous plants), a 36% increase in the average coverage of the sprayed testers was observed for the FCGA nozzles.

Table 2. Results of the theoretical coverage (P_t) for the GAT 110-02 nozzle and pressure 0.4 MPa and the average degree of coverage (P_{ss}) for individual coefficients of spraying surfaces
Tab. 2. Wyniki teoretycznego stopnia pokrycia (P_t) dla rozpylacza GAT 110-02 i ciśnienia 0.4 MPa oraz średniego stopnia pokrycia (P_{ss}) dla poszczególnych współczynników powierzchni opryskowych

W_{po}	Horizontal surfaces (a) [cm^2]		Vertical surfaces (b) [cm^2]				Average degree of coverage P_{ss} [cm^2]
			transverse		longitudinal		
	top	bottom	approach	depart	right	left	
0.25	7.05	0	0.43	0.09	0.23	0.10	1.32
0.5	5.88	0	0.71	0.14	0.38	0.17	1.21
0.75	5.04	0	0.91	0.19	0.48	0.22	1.14
1.0	4.41	0	1.07	0.22	0.56	0.26	1.09
1.25	3.92	0	1.19	0.24	0.63	0.29	1.04
1.5	3.53	0	1.28	0.26	0.68	0.31	1.01
1.75	3.20	0	1.36	0.28	0.72	0.33	0.98
2.0	2.94	0	1.42	0.29	0.75	0.35	0.96

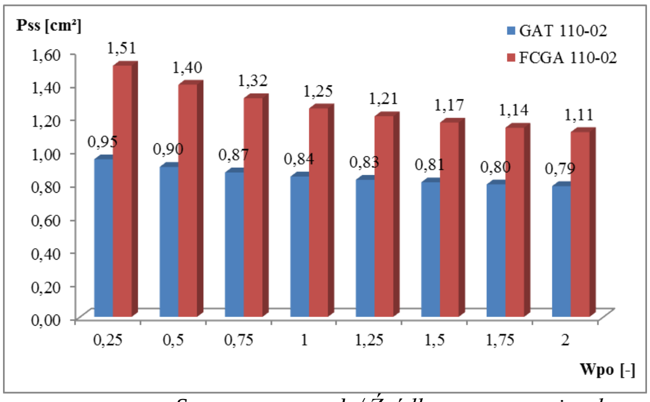
Source: own work / Źródło: opracowanie własne

Table 3. Results of the multivariate analysis of variance
Tab. 3. Wyniki wieloczynnikowej analizy wariancji

Factor	P values				
	Surfaces				
	Horizontal top	Vertical approach	Vertical departure	Vertical right	Vertical left
Nozzle	0.0000	0.0000	0.0000	0.0000	0.0000
Spray surface coefficient	0.0000	0.0000	0.0009	0.0000	0.0000
Pressure	0.0000	0.0000	0.1183	0.0000	0.2293

Source: own work / Źródło: opracowanie własne

For the GAT 110-02 nozzle, with the change of W_{po} =2 to W_{po}=0.5 at the pressure of 0.2 MPa, a 20% increase of the average coverage was noted. With the pressure of 0.4 MPa, a smaller difference of the average coverage (5%) was observed between the FCGA and GAT nozzles. At lower pressures there was a greater difference in the average coverage of the sprayed plants for the tested nozzles (Fig. 2 and 3).



Source: own work / Źródło: opracowanie własne

Fig. 2. The average degree of coverage of the sprayed objects with the pressure of 0.2 MPa for the selected nozzles and the assumed coefficient of spray surfaces
Rys. 2. Średni stopień pokrycia opryskiwanych obiektów przy ciśnieniu 0.2 MPa dla wybranych rozpylaczy i przyjętego współczynnika powierzchni opryskowych

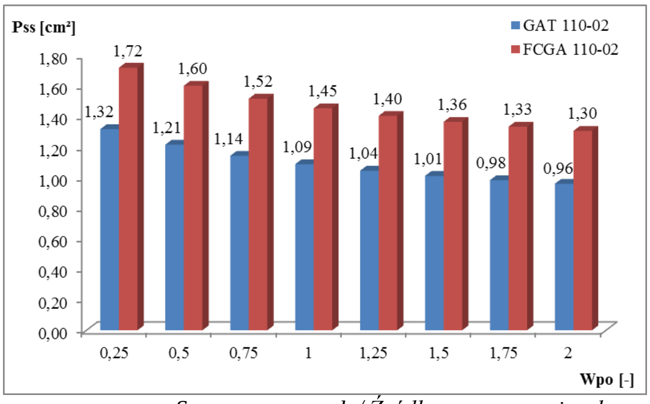


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Fig. 3. The average degree of coverage of the sprayed objects with the pressure of 0.4 MPa for the selected nozzles and the assumed coefficient of spray surfaces
Rys. 3. Średni stopień pokrycia opryskiwanych obiektów przy ciśnieniu 0.4 MPa dla wybranych rozpylaczy i przyjętego współczynnika powierzchni opryskowych

The results of the research confirm the need to analyse the potential of the nozzles in terms of their ability to cover the sprayed objects characterised with by different morphological features. The interpretation of the research results is consistent with the previous experiments in which the authors emphasise the great importance of the selection of the nozzle for performing the plant protection treatments [6-11, 14, 15]. Thanks to the coefficient of spray surfaces it will be possible to increase the efficiency of spraying plants while limiting the loss of the utility liquid and therefore the environmental pollution. This will result in high quality and efficiency of the procedure [1, 12, 13].

It has also been observed that in the case of plants for which the coefficient of spray surface is smaller than 1, (the superiority of the horizontal surfaces), the single-stream nozzle has covered the studied surfaces better with the liquid. On the other hand, when there are more vertical surfaces in the plants (Wpo>1), the difference in the coverage of the sprayed surfaces decreased, which means that both the single- and double-stream nozzles can be used for spraying.

The multivariate analysis of variance has been performed for the purposes of the statistical development of the results, which are presented in Tab. 3. The data shown in the table indicate that the tested factors had an important effect (at the significance level α = 0.05) on the degree of coverage of the sprayed objects, except for the lack of significant influence of the pressure values on the degree of coverage of the vertical departure and left surfaces.

4. Conclusions

1. A higher average degree of coverage is noted for single-stream nozzles than for double-stream nozzles.
2. In case when the coefficient of spray surface is smaller than the unity, it is preferable to use single-stream nozzles. For the FCGA 110-02 nozzle, with the change of W_{po} =2 to W_{po}=0.5 at the pressure of 0.2 MPa, a 36% increase of the average coverage was noted.
3. At lower pressures, there was a greater difference in the average coverage of the sprayed plants for the tested nozzles.

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