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THE AVERAGE COVERAGE OF SPRAYED OBJECTS DEPENDING ON THE COEFFICIENT OF SPRAY SURFACE FOR THE SELECTED NOZZLES

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ABSTRACT

The primary objective of the experiment was to determine the average coverage of the sprayed liquid on the plant surface according to the adopted coefficient of the spray surface of plants (W_{po}). Examinations were performed under laboratory conditions, using a sprayer, which was moving with a constant operating speed, at various operating pressures. During the study four types of nozzles were used: standard and ejector. They sprayed objects, which were artificial plants, equipped with probes in the form of water-sensitive papers. Probes were placed on the horizontal and vertical surfaces of the plants. The degree of coverage was determined by computer image analysis. The analysis of obtained results showed that the coefficient of the surface spray has a significant impact on the size of the average surface coverage of sprayed objects. It was found that in case where the W_{po} <1, standard nozzles are better for spraying, and when $W_{po} > 1$, ejector nozzles and standard double may be used more successfully.

Introduction

Currently, in the field of plant protection, technology seeks to reduce the use of pesticides while achieving the more efficient use of plant protection products. The primary tasks posed to plant protection technology include: selection of appropriate technical and operational parameters for the performed crop protection procedures, and reducing spray drift during the spraying agricultural fields (Godyń et al., 2012). One of the deciding factors for obtaining the best quality, and hence the effectiveness of spraying treatments, is the selection of the right form and type of the sprayer. The analysis of the quality of work of the commercially available nozzles can help the user to select the best equipment. The issue of selecting a relevant agent used to assess the quality of a spraying session is also important.

The rate of the coverage degree of objects is one of the basic criteria for assessing the quality of nozzles. The coverage degree is defined as the ratio of the surface covered with liquid to the total surface of the tested piece and it is expressed in percentage (Hołownicki et al., 2002, Lipinski et al., 2007; Godyń et al., 2008; Szewczyk et al., 2012). Studies on the coverage degree are most often carried out with water-sensitive papers, which are fixed to the leaf blade of the plant (in field conditions) or artificial plants (in the laboratory) (Szewczyk, et al., 2012; Foque et al., 2012, Lipinski et al. 2007).

Another indicator that determines the quality of the treatment is the size of the spray application of liquid sprayed on the plant. The application indicator is defined as the ratio of the weight of the liquid or preparation per unit area and is measured in μg substance which is on the sprayed surface (Hołownicki et al., 2002; Godyń et al., 2008). The indicator provides information on the actual dose of liquid / preparation which was used during the spraying operation, but does not give information about the uniformity of the distribution of liquid on a sprayed surface (Hołownicki et al., 2002; Zhu et al., 2004, Gaskin, et al., 2009).

Another indicator used to assessing the quality of work used for the treatment nozzle is the distribution of liquid under the nozzles. This ratio depends on the condition of the nozzle. The larger is an aperture of the spray nozzle the unit changes the flow and irregularity of the spray liquid is greater. The occurrence of the larger droplets results in higher probability of falling drops from sprayed surfaces (Koszel and Sawa 2006; Koszel and Hanusz 2008; Koszel 2009). Weather conditions (e.g. wind speed and direction) and the parameters of the performed procedures (e.g. working speed) are also important during the precipitation of liquid on the plant (Szewczyk and Wilczok 2008; Szewczyk and Łuczycka 2010).

The discussed indicators do not allow a full assessment of the quality of the spraying session. Łuczycka et al., (2014) argue that the additional information in the evaluation of spraying can provide the user with the average coverage index of the sprayed objects and the index of inequality of coverage of the sprayed objects.

The aim of examinations carried out was to determine the average surface coverage of the sprayed objects, depending on the coefficient of the spray surface, by a constant speed sprayer and various pressures for the selected types of nozzles.

Materials and methods

The research was conducted in the laboratory of the Institute of Agricultural Engineering at the University of Environmental and Life Sciences in Wroclaw. The 4 nozzles, selected for the experiment, have the same intensity of the liquid discharge but different construction and method of operation, namely:

A – a double stream air injector nozzle,

B – single-ejector nozzle (flat spray emitted from the liquid stream with a deviation of about 10-15°),

C – a double stream standard nozzle,

D – single-standard nozzle, flat spray emitted from the liquid.

Research of the coverage degree was carried out using a sprayer, which was designed and manufactured at the Institute of Agricultural Engineering at the Wroclaw University of Environmental and Life Sciences. The scheme stand and its principle of operation are well described in the works: Szewczyk 2010 Szewczyk et al., 2012 Łuczycka et al., 2014. During the tests a constant operating speeds of 8 $km \cdot h^{-1}$, pressure liquid 0.2 and 0.4 MPa, and the height of the nozzles of 0.5 m from the sprayed object were used. At the pressure of 0.2 MPa the dose of liquid was equal to 97.5 $l \cdot ha^{-1}$, and at the pressure of 0.4 MPa it was 137 $l \cdot ha^{-1}$. The sprayed objects were three artificial plants, equipped with probes in the form of water-sensitive papers, which were placed on specific areas: vertical transverse approach (Anj), vertical transverse leaving (Aoj), vertical longitudinal left (Apl), vertical longitudinal right (App), a horizontal upper (Apg) and horizontal lower (Apd). The study used three artificial plants, which accounted for the next repetition. The degree of coverage was determined using the computer image analysis method. After converting probes on the digital image, using a scanner in Adobe Photoshop 7.0, the percent of sprayed surface has been read. The degree of coverage was obtained from the averaged coverage on three randomly selected fragments of 1 cm^2 on the test piece of paper. This was repeated for all test surfaces. For further analysis, the results were averaged from three plants separately for each test surface: vertical transverse approach (Anj), vertical transverse leaving (Aoj), the vertical longitudinal left (Apl), vertical longitudinal right (App), horizontal upper (Apg) and a horizontal lower (Apd).

The spray plants surface coefficient was determined as the ratio of the vertical projections sprayed plants for horizontal surfaces projections by formula 1.

$$W_{po} = \frac{projection\ vertical\ surface}{projection\ horizontal\ surface} \quad (-) \qquad (1)$$

Table 1 shows the projected surface of horizontal and vertical adopted values for the surface sprayed plants coefficient, an exemplary plant with an area of 100 cm^2.

Table 1.
Total surface of horizontal and vertical projections for each sprayed plants coefficient

Number	Coefficient of sprayed surface W_{po}	Projection horizontal surface (a) (cm^2)		Projection vertical surface (b) (cm^2)			
				transverse		longitudinal	
		upper	lower	approach	leaving	right	left
1	0.25	40	40	5	5	5	5
2	0.50	33.33	33.33	8.33	8.33	8.33	8.33
3	0.75	28.57	28.57	10.71	10.71	10.71	10.71
4	1.00	25	25	12.5	12.5	12.5	12.5
5	1.25	22.22	22.22	13.89	13.89	13.89	13.89
6	1.50	20	20	15	15	15	15
7	1.75	18.18	18.18	15.91	15.91	15.91	15.91
8	2.00	16.66	16.66	16.67	16.67	16.67	16.67

Results and discussion

The results of the coverage degree of sprayed objects for all the examined nozzles are shown in figures 1-4.The graphs show the degree of coverage for the following probes: vertical transverse approach (Anj), vertical transverse leaving (Aoj) vertical longitudinal left (Apl), vertical longitudinal right (App) and horizontal upper (Apg). The method used for measuring the degree of coverage showed no traces of drops on the lower surface of the horizontal probe (Apd), therefore this object was skipped in the analysis of results. An analysis of the graphs, presented in figures 1-4 shows that the pressure with which we spray has a little effect on the degree of coverage of the probes for both nozzles: standard and air-injector. At the coverage of the horizontal upper surface of the probe, when standard nozzles – C and D were used 20-25% better cover of the probe at a pressure of 0.4 MPa was reported. In other cases, differences in the degree of coverage during tests at the pressure of 0.2 and 0.4 MPa did not exceed 5%.

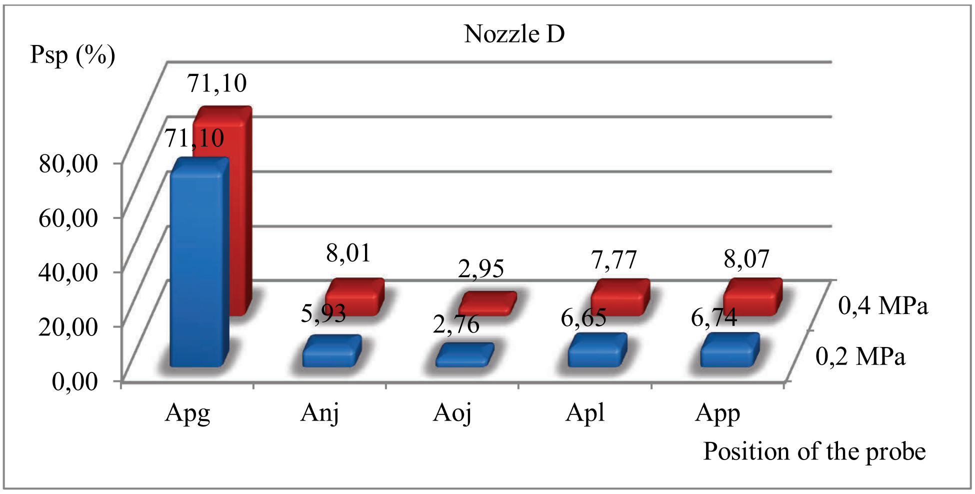

Figure 1. Degree of coverage (Psp) of probes for nozzle D at the pressure of 0.2 and 0.4 MPa

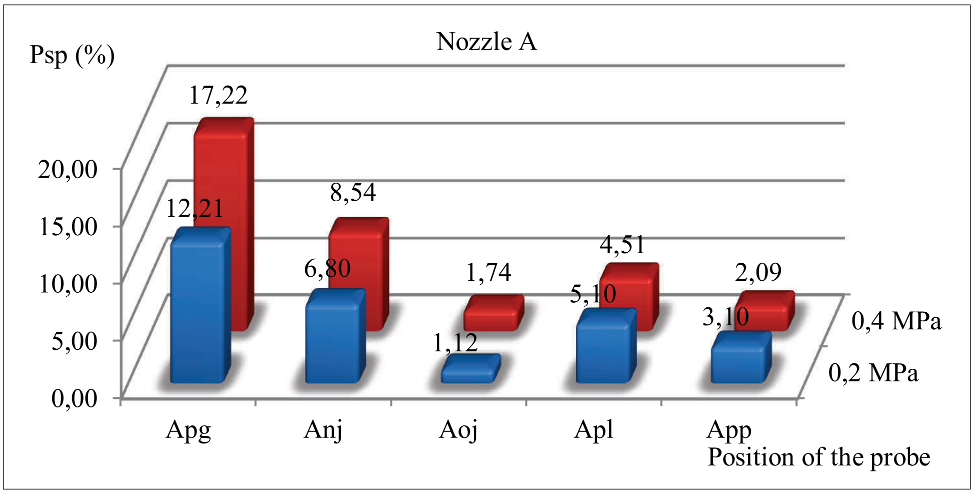

Figure 2. Degree of coverage (Psp) of probes for nozzle A at the pressure of 0.2 and 0.4 MPa

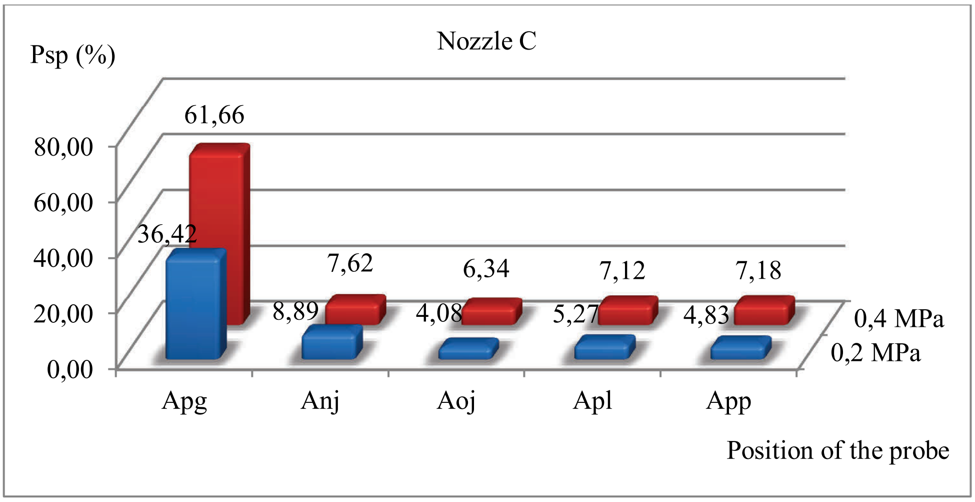

Figure 3. Degree of coverage (Psp) of probes for nozzle C at the pressure of 0.2 and 0.4 MPa

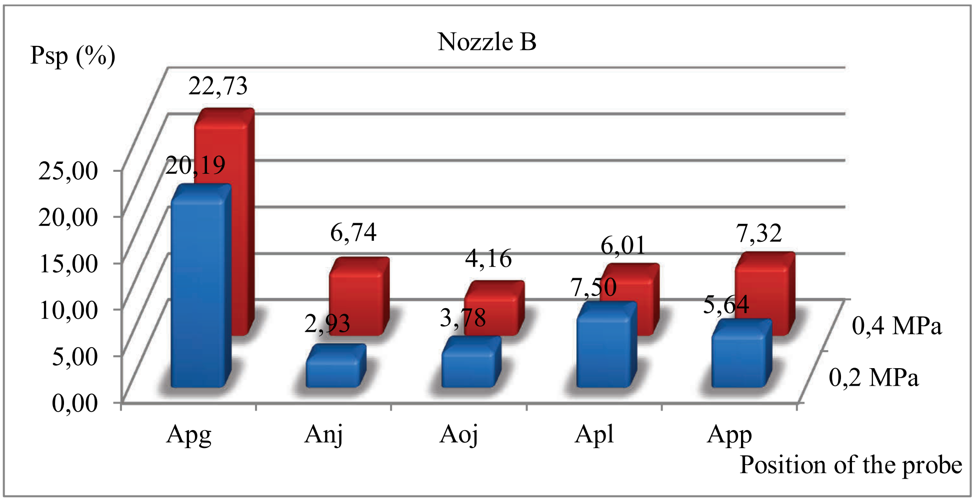

Figure 4. Degree of coverage (Psp) of probes for nozzle B at the pressure of 0.2 and 0.4 MPa

All the examined types of nozzles covered the best, horizontal upper probes although in very different degrees. The maximum coverage of horizontal upper probes was obtained using a standard D nozzle and it amounted to 67.31% for the 0.4 MPa pressure used in the tests. The smallest horizontal upper cover probe was recorded using a nozzle A (double stream air injector), and it amounted to 12.2% at the pressure of 0.2 MPa, and 17.2% at the pressure of 0.4 MPa.

The figures present 5-8 aggregate coverage (Ps) of the sprayed probes, depending on the coefficient of surface spray (Wpo) and the pressure of the liquid to spray examined types. Analysis of fig. 5-8 shows that the standard nozzles C and D have bigger variability coverage, compared to the nozzles ejector A and B.

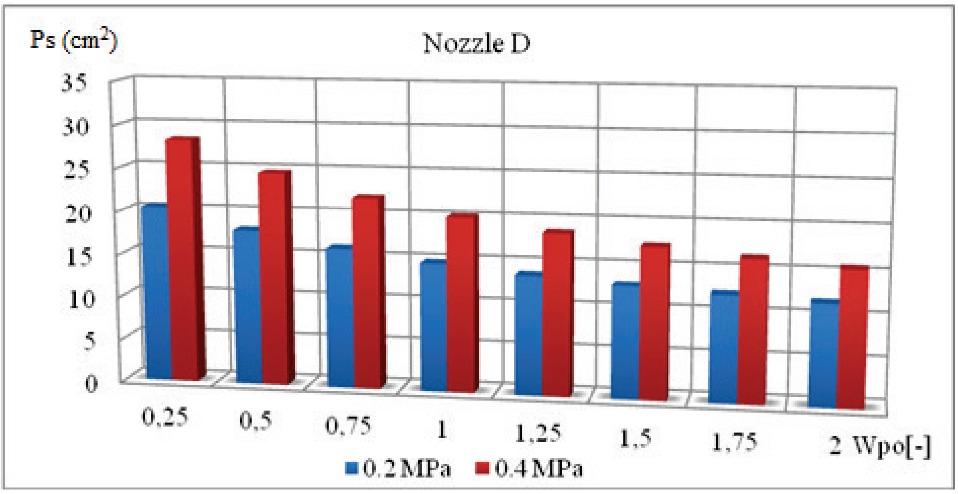

Figure 5. Total covering (Ps)of sprayed objects depending on the Wpo with pressure liquid 0.2 and 0.4 MPa for nozzle D

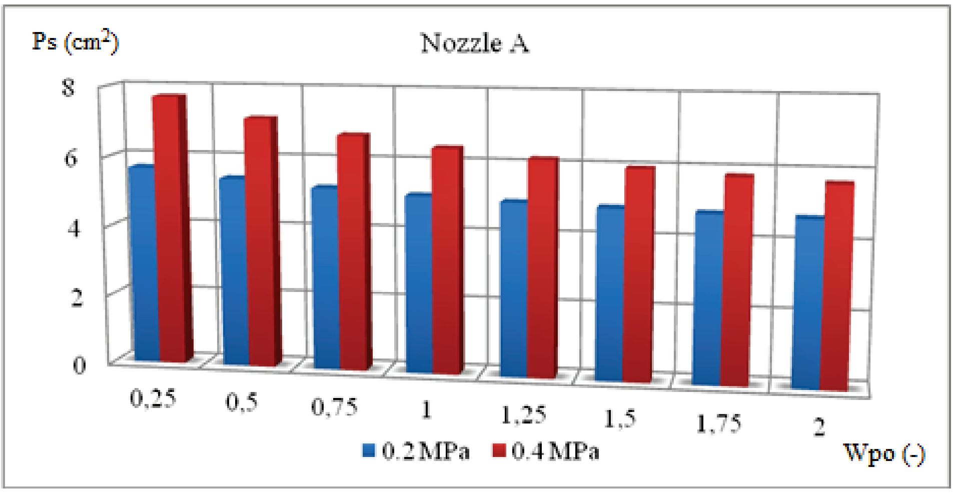

Figure 6. Total covering (Ps) of the sprayed objects depending on the Wpo with pressure liquid 0.2 and 0.4 MPa for nozzle A

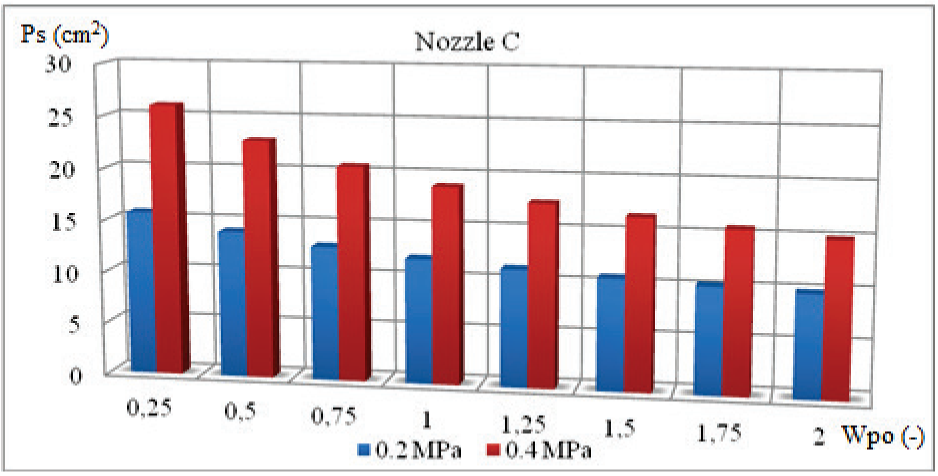

Figure 7. Total covering (Ps) of the sprayed objects depending on the Wpo with pressure liquid 0.2 and 0.4 MPa for nozzle C

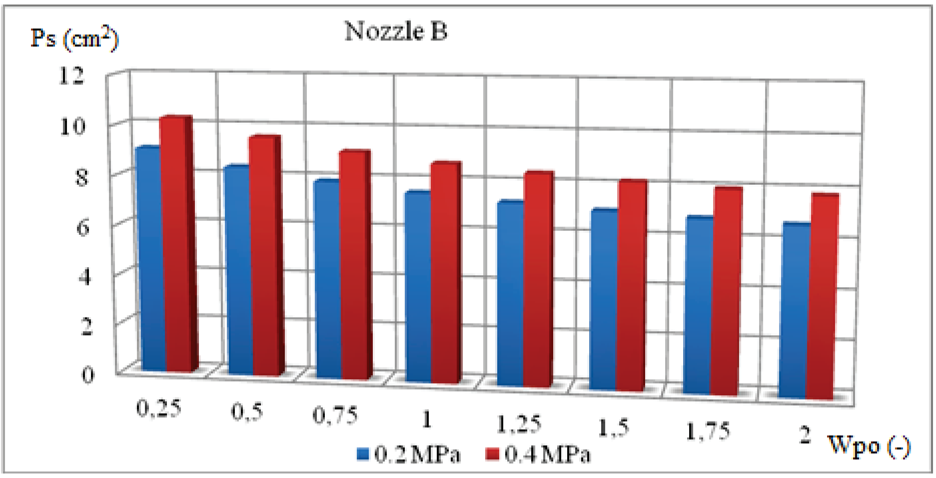

Figure 8. Total covering (Ps) of the sprayed objects depending on the Wpo with pressure liquid 0.2 and 0.4 MPa for nozzle B

When changing the coefficient of spraying the surface with the value of Wpo = 2 to Wpo = 0.5 for nozzle D, the coverage has increased the summary probes from 15.5 to 25.5 cm² of the sprayed surface, which is a 64% increase in the coverage of probes. In the case of the sprayer D, the pressure with which the research was performed did not significantly affect the total coverage area (fig. 5). This is a clear example of the need to analyze the possibility of nozzles in terms of their ability to cover the sprayed objects. In the case of the nozzles ejector (e.g. B) a change in the values spray of the surface with Wpo = 2 to Wpo = 0.5 caused an increase in surface coverage of probes only by 23%. This is another example of the characteristic ability of individual nozzles "specializing" in spraying differently situated objects (vertical or horizontal).

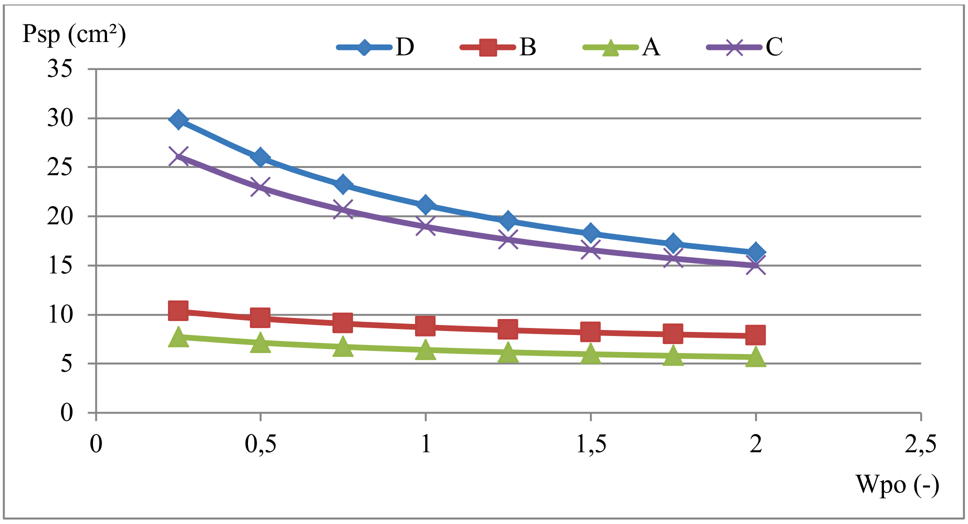

Figure 9. Cover sprayed object with the selected nozzles according to the Wpo at a liquid pressure of 0.4 MPa

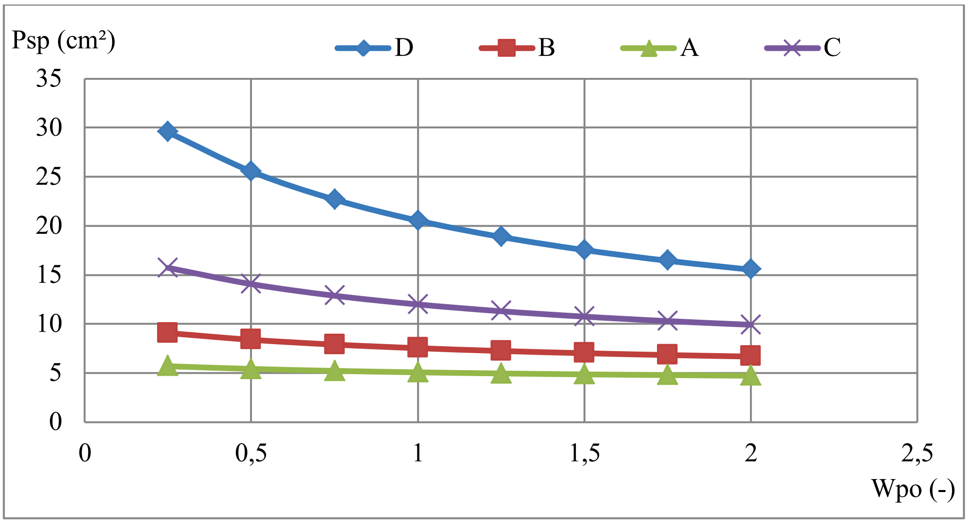

Figure 10. Cover sprayed object with the selected nozzles according to the Wpo at a liquid pressure of 0.2 MPa

Comparison of the total cover of the surface of the selected nozzles according to the surface coefficient of spraying at the pressure of 0.4 MPa is shown in fig. 9, and at the pressure of 0.2 MPa in Fig. 10. At an operating pressure of 0.2 MPa and Wpo = 0.5 the total coverage by spray liquid probes one stream standard nozzle – D is about 81% higher than their coverage by standard spray of a double stream nozzle – C (25.4 cm²). In contrast to the coefficient surface Wpo = 2 the differential coverage of these nozzles was 57%, and in this case it is equal to the area of 5.6 cm². At the operating pressure of 0.4 MPa the total coverage by spray liquid probes of one stream – D is about 13% higher than the nozzle of double stream – C or 3 cm² for the surface coefficient 0.5. For coverage the surface coefficient 2 difference through the nozzles is 9% (1.3 cm²).

Table 2.
Results of the multi-factor analysis of variance of the impact of the nozzles type and the speed of spraying on the average covering degree

Factor	The level of significance α of the effects of factors.	
	F	P
Type of nozzle	66.756	0.0000
Pressure	31.130	0.0000

The results were obtained to confirm the observations from the graphs according to the statistical analysis. The results of this analysis are shown in Table 2. The analysis of the data contained there, that examined factors such as the type of spray and pressure, have had a significant (α <0.05) effect on the average degree of coverage on the intended objects.

Conclusion

1. For nozzles selected to investigate the pressure change with which we operated, there is no apparent effect on the coverage degree of the sprayed probes (e.g. nozzle D).
2. The analysis of the results showed that for the larger surfaces of the projections of the Wpo <1 it is preferable to use spray nozzles in standard, and with a larger vertical projection surface of the plant (Wpo>1) ejector nozzles and standard case, double can be used more successfully. Changing the value of Wpo from 2 to 0.5 significantly increased the total coverage surface of the spray using nozzles C and D. At sprays ejector for example B changing the value of the Wpo = 2 Wpo = 0.5 increased the coverage by the total of 23%.
3. The analysis of the obtained results confirmed the assumption that the value of the coefficient of spray surface had a significant impact on the surface coverage of the total of all probes employed on the artificial plant, because when we change the coefficient Wpo = 2 Wpo = 0.5 it shows an increase in the covered surface to 81 % (nozzle D).
4. Based on the multi-factor analysis of variance, it was found that the average degree of coverage is affected by two examined factors (pressure and nozzle).

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ŚREDNIE POKRYCIE OPRYSKIWANYCH OBIEKTÓW W ZALEŻNOŚCI OD WSPÓŁCZYNNIKA POWIERZCHNI OPRYSKOWYCH DLA WYBRANYCH ROZPYLACZY

Streszczenie. Celem eksperymentu było określenie średniego pokrycia opryskiwanej powierzchni rośliny, w zależności od przyjętego współczynnika powierzchni opryskowych (W_{po}). Badania wykonano w warunkach laboratoryjnych, przy użyciu opryskiwacza, który poruszał się ze stałą prędkością roboczą, ale przy różnych ciśnieniach pracy. Do badań użyto czterech typów rozpylaczy (standardowych i eżektorowych). Opryskiwanymi obiektami były sztuczne rośliny zaopatrzone w próbniki w postaci papierków wodoczułych, które umieszczano na powierzchniach poziomych i pionowych. Stopień pokrycia określono metodą komputerowej analizy obrazu. Analiza uzyskanych wyników badań wykazała, że współczynnik powierzchni opryskowych, ma znaczący wpływ na wielkość średniego pokrycia powierzchni opryskiwanych obiektów. Stwierdzono również, iż w przypadku, kiedy $W_{po}<1$ korzystniej jest do oprysku używać rozpylaczy standardowych, a kiedy $W_{po}>1$, z większym powodzeniem można stosować rozpylacze eżektorowe oraz standardowe dwustrumieniowe.

Słowa kluczowe: stopień pokrycia, współczynnik powierzchni opryskowych, rozpylacz, opryskiwanie