Beata CIENIAWSKA[1], Deta ŁUCZYCKA[1], Jan ČERVINKA[2], Tomasz R. SEKUTOWSKI[3], Katarzyna DEREŃ[1]
[1] Wrocław University of Environmental and Life Sciences, Institute of Agricultural Engineering,
ul. Chełmońskiego 37A, 51-630 Wrocław, Poland
[2] Mendel University in Brno, Faculty of AgriSciences, Czech Republic
[3] Institute of Soil Science and Plant Cultivation – National Research Institute, Puławy, Poland
Department of Weed Science and Tillage Systems, ul. Orzechowa 61, 50-540 Wrocław, Poland
e-mail: beata.cieniawska@upwr.edu.pl

DEPOSITION OF SPRAY LIQUID DEPENDING ON THE COEFFICIENT OF SPRAY SURFACES

Summary

In the assessment of the quality of treatment using the application indicator there is no information concerning the parametric characteristics of the sprayed plant. Therefore, the aim of this study was to determine the application of the utility liquid depending on the coefficient of the position of the spray surfaces with the use of the selected single- and dual- spray nozzles. The studies were performed at the Institute of Agricultural Engineering of the University of Environmental and Life Sciences in Wroclaw, in laboratory conditions. The carrier of nozzles acting as an independent sprayer was used for spraying. The coefficient of the position of the spray surfaces as the relation of surfaces of vertical projections and to the surfaces of horizontal projections was determined using artificial plants by appropriately setting its sprayed surfaces. Results of the tests and their analysis showed the influence of the position of spray surfaces coefficient on the deposit of the spray liquid.
***Key words**: deposition, nozzle, spraying, coefficient of spray surfaces*

NANIESIENIE CIECZY UŻYTKOWEJ W ZALEŻNOŚCI OD WSPÓŁCZYNNIKA POWIERZCHNI OPRYSKOWYCH

Streszczenie

W ocenie jakości zabiegu z wykorzystaniem wskaźnika naniesienia brakuje informacji dotyczącej parametrycznej charakterystyki opryskiwanej rośliny. Dlatego też celem pracy było określenie naniesienia cieczy użytkowej zależności od współczynnika położenia powierzchni opryskowych z zastosowaniem wybranych rozpylaczy jedno i dwustrumieniowego. Badania wykonano w Instytucie Inżynierii Rolniczej Uniwersytetu Przyrodniczego we Wrocławiu, w warunkach laboratoryjnych. Do opryskiwania użyto nośnika rozpylaczy działającego jak samodzielny opryskiwacz. Współczynnik położenia powierzchni opryskowych jako stosunek powierzchni rzutów pionowych i do powierzchni rzutów poziomych określano z zastosowaniem sztucznych roślin odpowiednio ustawiając jej opryskiwane powierzchnie. Wyniki badań i ich analiza wykazały wpływ współczynnika powierzchni opryskowych na wielkość naniesienia cieczy użytkowej.
***Słowa kluczowe**: naniesienie, rozpylacz, współczynnik powierzchni opryskowych, opryskiwanie*

1. Introduction

The effectiveness of the treatment, among others, is determined by the level and uniformity of the application of the utility liquid, what is closely connected with the appropriate amount of the active substance of the applied plant protection products. For predicting the right effectiveness one can also use the quality indicators of the treatment, which include the uniformity of the decomposition of liquid precipitation and the degree of coverage of the sprayed objects [9, 10]. Many authors in their publications indicate that the effectiveness of the treatment should be closely linked to the use of the smallest possible amount of pesticides, which, however, are necessary to ensure a high quality crops and their highest possible amount [3, 8]. This is an extremely important aspect in the era of the increasing world population. At the same time, you should keep in mind the basic conditions of the use of pesticides, and namely that they should be used only where it necessary and in a way only when this is necessary and in a way that does not harm the environment, consumers and users of sprayers [5, 6]. The last condition requires a relatively simple and complex method of using quality parameters of spraying. One that would make it possible to draw practical conclusions regarding the applied nozzle and work parameters to ensure the most effective treatment. According to the authors, to achieve this one should take into consideration the conditions arising from the characteristics of the sprayed object [2]. Moreover, the authors believe that the analysis of results of such studies will greatly facilitate the adaptation of the adequate nozzle and work parameters of the sprayer for spraying the specific crops in the field.

Therefore, at the Institute of Agricultural Engineering there were undertaken studies to determine the size of the utility liquid application depending on the coefficient of spray surfaces using the selected single- and dual-spray nozzles.

2. Material and Methods

The studies were performed in the Institute of Agricultural Engineering of the University of Environmental and Life Sciences in Wroclaw, in laboratory conditions, on a specially prepared boom sprayer (fig. 1.) The fundamental element of the stand was the carrier of nozzles, which moved on the designated route. In the first section, the carrier obtained the desired speed, then it drove through the 10-metre measurement section, and in the last stage it stopped on the final section. The nozzle carrier while moving on the measurement section sprayed with the liquid with the fluorescent label - BSF three artificial plants, constituting repetitions.

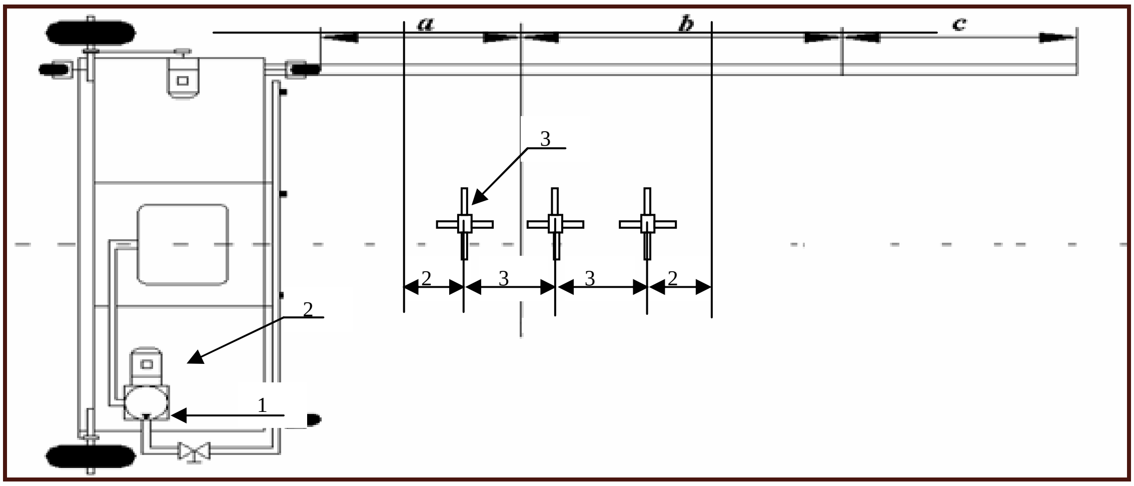

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Fig. 1. Schematic representation of the measurement stand: a – run line, b – a measurement line, c – ending line, 1 – sprayers carrier, 2 – nozzles, 3 – an artificial plant
Rys. 1. Schemat stanowiska badawczego: a – odcinek rozbiegowy, b – odcinek pomiarowy, c – odcinek końcowy, 1 – nośnik rozpylaczy, 2 – rozpylacze, 3 – sztuczna roślina

The studies consisted in spraying the probes of the filter paper, which were placed on the artificial plant. Probes were labelled as surfaces: vertical overrunning (A_{nj}), vertical stellar (A_{oj}), vertical right (A_{bp}), vertical left (A_{bl}), horizontal top (A_{pog}), horizontal bottom (A_{pod}) (fig. 2).

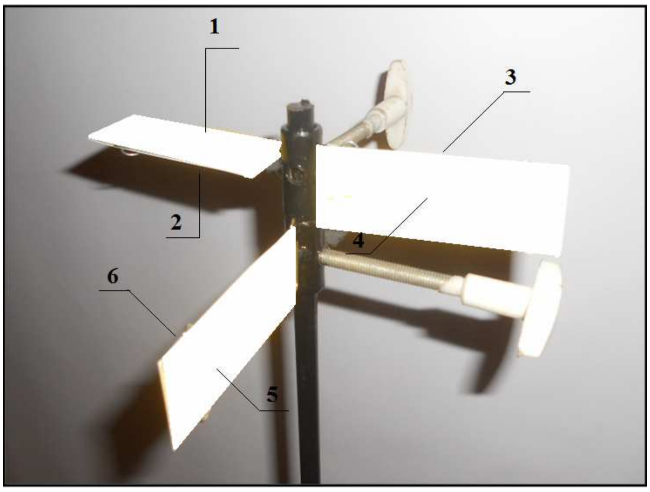

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Fig. 2. View of an artificial plant with marked researched facilities: 1 – upper level (A_{pog}), 2 – lower level (A_{pod}), 3 – vertical transverse leaving (A_{oj}), 4 – vertical transverse approach (A_{nj}), 5 – vertical longitudinal right (A_{bp}), 6 – vertical longitudinal left (A_{bl})
Rys. 2. Obraz sztucznej rośliny z próbnikami: 1 – powierzchnia pozioma górna (Apog), 2 – powierzchnia pozioma dolna (Apod), 3 – powierzchnia pozioma odjazdowa (Aoj), 4 – powierzchnia pionowa najazdowa (Anj), 5 – powierzchnia pionowa prawa (Abp), 6 – powierzchnia pionowa lewa (Abl)

The quantitative analysis of the fluorescent label extracted from the probes (Briliant Sulfo Flavine) was conducted using the luminescence spectrometer (Perkin Elmer LS55) at the Institute of Horticulture in Skierniewice. The concentration of the BSF was calculated by taking into account:

- measured concentration of BSF,
- sample surface,
- coefficient of spray surface (W_{po}).

The coefficient of the spray surface was determined based on the formula proposed by the authors, taking into account the ratio of the sprayed surfaces in the vertical and horizontal projection.

$$W_{po} = \frac{projection \cdot of \cdot vertical \cdot surfaces}{projection \cdot of \cdot horizontal \cdot surfaces} \qquad (1)$$

For the studies there were selected the coefficients: 0.25; 0.50; 0.75; 1; 1.25; 1.50; 1.75; 2. Individual deposition of the spray liquid is the result of the concentration of the BSF mark on the sprayed object. While applying a total usable liquid surface at a variable rate of the obtained spray multiplying the concentration of the marker on each BSF sprayed object (expressed in $\mu g \cdot cm^{-2}$) by the projected horizontal or vertical area. Appearance of the deposition of spray liquid was evaluated on a Perkin Elmer LS 55 luminescent fluorometer. To measure concentration of the BSF marker, 30 ml deionized water was first poured, then shaken for 15 minutes at a special shaking station of 162 $cycles \cdot min^{-1}$. It is also important that in each of the studied cases, a fixed sum of vertical and horizontal planes of 100 cm^2 was assumed. The amount of the projected horizontal and vertical surface for respective area ratios of spray are shown in table 1. In the experiments there were used nozzles: CVI 11002, CVI TWIN 11002, with the spraying speeds – 8 $km \cdot h^{-1}$ and pressure of liquid – 0,2 MPa , the distance between nozzles and artificial plants was 50 cm.

Table 1. Surface area of horizontal and vertical projections for individual coefficients of spray surfaces
Tab. 1. Powierzchnia rzutów poziomych i pionowych dla poszczególnych współczynników powierzchni opryskowych

Coefficient of spray surface W_{po}	Horizontal surface [cm^2]		Vertical surface [cm^2]			
			transverse		longitudinal	
	upper	lower	approach	leaving	right	Left
0.25	40	40	5	5	5	5
0.50	33.335	33.335	8.3325	8.3325	8.3325	8.3325
0.75	28.57	28.57	10.715	10.715	10.715	10.715
1.00	25	25	12.5	12.5	12.5	12.5
1.25	22.22	22.22	13.89	13.89	13.89	13.89
1.50	20	20	15	15	15	15
1.75	18.18	18.18	15.91	15.91	15.91	15.91
2.00	16.665	16.665	16.6675	16.6675	16.6675	16.6675

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3. Results and discussion

The test results of the utility liquid application are presented in the diagrams (fig. 3-7).

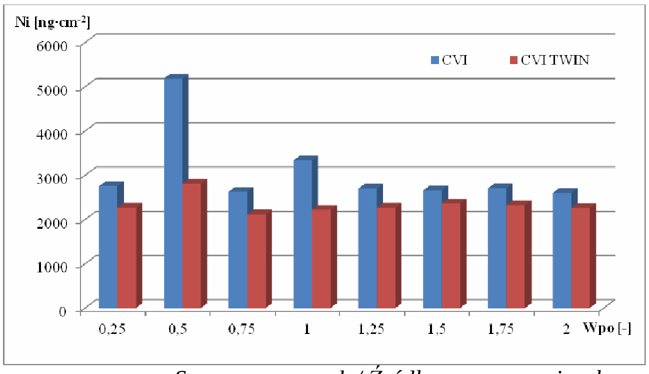

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Fig. 3. Individual deposition of spray liquid on the horizontal surfaces
Rys. 3. Jednostkowe naniesienie cieczy użytkowej na powierzchnie poziome

Fig. 3 presents test results of the individual deposition of spray liquid on the horizontal surfaces. The deposit of the spray liquid was greater when single-spray nozzles were used.

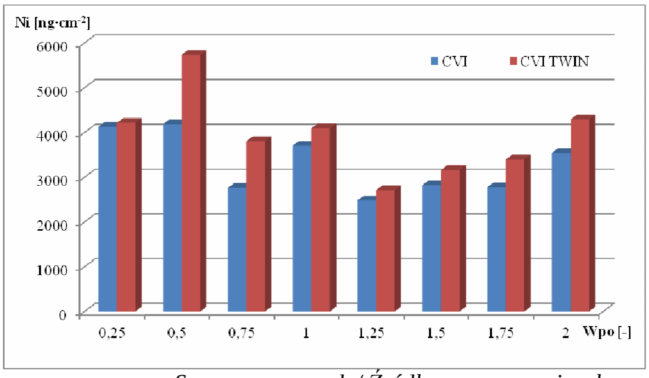

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Fig. 4. Individual deposition of spray liquid on vertical surfaces
Rys. 4. Jednostkowe naniesienie cieczy użytkowej na powierzchnie pionowe

The test results of the utility liquid application on the vertical surfaces are presented on fig. 4. Higher values of spray liquid deposition with dual flat fan nozzles were obtained.

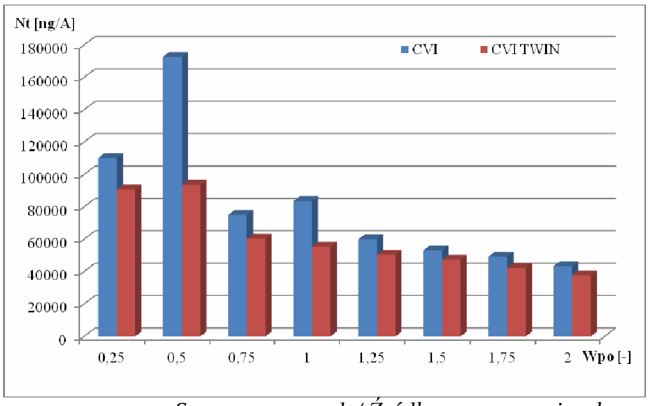

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Fig. 5. The total deposition of spray liquid on the horizontal surfaces
Rys. 5. Całkowite naniesienie cieczy użytkowej na powierzchnie poziome

The test results of the total deposition of spray liquid on the horizontal surfaces indicate, that the higher values were noted for the single nozzle. Fig. 6 presents the test results of the total deposition of spray liquid on the vertical surfaces. Similar in the case of individual deposition of spray liquid on the tested vertical surfaces, the higher values for the dual stream nozzle were obtained.

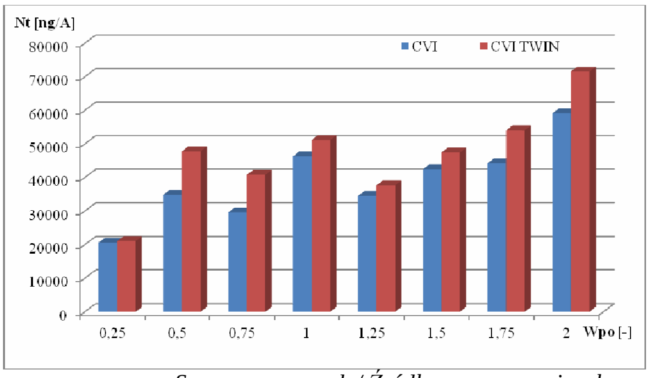

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Fig. 6. The total deposition of spray liquid on the vertical surfaces
Rys. 6. Całkowite naniesienie cieczy użytkowej na powierzchnie pionowe

Total deposition of spray liquid to vertical and horizontal surfaces is presented in figure 7. In each of the analyzed cases, higher values were obtained for the CVI single-stream nozzle, with the exception of Wpo 1.75 and 2, where higher values for the CVI TWIN dual-stream nozzle were obtained.

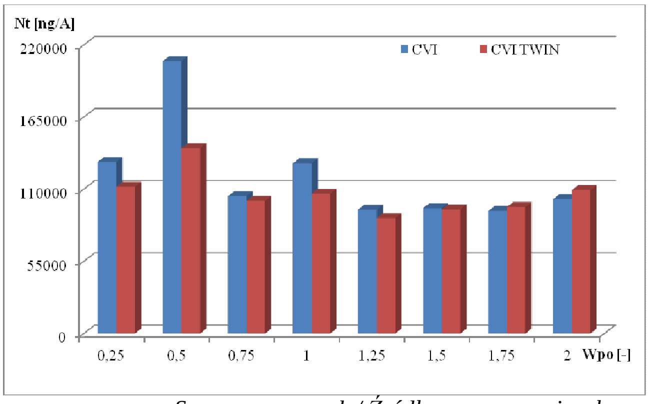

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Fig. 7. The total deposition of spray liquid
Rys. 7. Całkowite naniesienie cieczy użytkowej

For the statistical study of the results there was used the multivariate analysis of variance, which showed that the type of the applied nozzle and the coefficient of spray surfaces have a significant effect on the spray liquid deposition (tab. 2).

Table 2. Results of the multivariate variance analysis
Tab. 2. Wyniki wieloczynnikowej analizy wariancji

Factor	Value of the test function F	Value of the probability level p
Nozzle	17.8542	0.0000
Coefficient of the spray surfaces	1.5325	0.0131

Source: own work / Źródło: opracowanie własne

The study of liquid application was carried out using different fluorescent markers, synthetic dyes or chelates. So far, most of the experiments in evaluating the spray quality using a liquid application indicator have been carried out in orchard crops.

Other authors [7] studied the spray deposition in wheat and potato crops. The research was conducted using a variety of nozzles (XR, ID, Air Tec), as well as various auxiliary airflow systems (Kyndestoft, Hardi TWIN) and Släpduk. As a marker in experiments, nigrosine was used as a synthetic dye.

Scientists investigated the spray deposit on soybean with application of different application techniques. Copper oxychloride was used as a marker in those experiments. Quantitative measurements in this case were subject to copper ion, the content of which was evaluated using sprayed filter paper [4].

Researchers conducted field orchard studies which also used a conventional sprayer and an auxiliary air jet. In the experiments, the authors placed samplers in the form of filter paper at the base and at the top of the tree crown, at their centre and left and right. As a spray liquid, water with azo dye - tartrazine was used. During the conventional spray application, the smallest application pattern was obtained with a conventional sprayer of 20-40 ng · cm^{-2}. On the other hand, using a sprayer with an auxiliary air stream, the distribution of the liquid throughout the tree crown was uniform and was 40-60 ng·cm^{-2} [1].

4. Conclusions

1. The obtained results showed that in spraying artifical objects with the specified characteristics it can be clearly shown which kind of nozzles design may gave higher cumulative deposition of the spray liquid.
2. The analysis of measurements results of application size for particular sprayed surfaces, both the horizontal and vertical, showed the existence of differences in the level of obtained application using the nozzles selected for the tests. In many cases spraying of the horizontal surfaces with the single flat nozzle gave better effect. However, in case of spraying of vertical surfaces with dual flat fan nozzle more comparable amount of spray deposition were noted.
3. The deposition of spray liquid is significantly influenced (at the significance level α=0,05) by the type of the applied nozzle and the coefficient of the spray areas.

5. References

[1] Celen I., Durgut M., Avci G., Kilic E.: Effect of air assistance on deposition distribution on spraying by tunnel-type electrostatic sprayer. African Journal of Agricultural Research, 2009, 4 (12), 1392-1397.
[2] Cieniawska B., Łuczycka D., Szewczyk A.: Characteristics crop plants in the aspect of the process of spraying. Mechanization in Agriculture, 2014, 6, 29-33.
[3] Decaro R., Decaro Junior S., da Costa Ferreira M.: Deposit of pesticides without and with adjuvants on citrus seedlings following different intervals of artificial rain. Ciência Rural, 2016, 46 (1), 13-19.
[4] de Souza Christovam R., Raetano C., de Amaral Dal Pogetto M., Prado E., Júnior H., Gimenes M., Serra M.: Effect of Nozzle Angle and Air-Jet Parameters in Air-Assisted Sprayer on Biological Effect of Soybean Asian Rust Chemical Protection. Journal of Plant Protection Research, 2010, 50(3), 347-353.
[5] Heidary M.Al, Douzal J.P., Sinfort C., Vallet A.: Influence of spray characteristics on potential spray drift of field crop sprayers: A literature review. Crop Protection, 2014, 63, 120-130.
[6] Jürgens K., Fink-Kessler A., Keil F., Götz K.: Plant Protection: The Risk Mitigation of Endocrine Disrupting Pesticides Use Demands the Shared Responsibility of All within the Agricultural System. Journal of Agricultural Science and Technology A., 2011, 1, 629-640.
[7] Larsolle A., Wretblad P., Westberg C.: A comparison of biological effect and spray liquid distribution and deposition for different spray application techniques in different crops. Uppsala. 2002. ISSN 00283-0086.
[8] Świechowski W., Doruchowski G., Godyń A., Hołownicki R.: Spray application quality as affected by spray volume, nozzles and phenological growth stage of apples. Agricultural Engineering, 2014, 1 (149), 229-237.
[9] Zaidan S.E., Gadanha Jr, Casimiro D., Gandolfo M.A., Pontelli C.O., Mosquini W.W.: Performance of spray nozzles in land applications with high speed. Engenharia Agrícola, 2012, 32(6), 1126-1132.
[10] Zhai C Y, Zhao C J, Wang X, Li W, Li W, Zhu R X. Nozzle test system for droplet deposition characteristics of orchard air-assisted sprayer and its application. International Journal of Agricultural and Biological Engineering, 2014, 7(2): 122-129.