Marek BRENNENSTHUL, Beata CIENIAWSKA, Jarosław CZARNECKI, Weronika PTAK
Wrocław University of Environmental and Life Sciences
Institute of Agricultural Engineering, ul. Chełmońskiego 37, 51-630 Wrocław, Poland
e-mail: marek.brennensthul@upwr.edu.pl

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EVALUATION OF EXPOSURE OF THE OPERATORS ON THE CONTACT WITH THE PLANT PROTECTION PRODUCTS DURING THE SPRAYING PROCESS

Summary

Plant protection products are one of the most dangerous substances in the agricultural working environment. The application of plant protection products by the broken implements or by wrong techniques can create the threats both for the operators, other people and for natural environment. The objective of this research was the evaluation of exposure of the sprayer operator on the liquid spray. Research was conducted for two types of the manual handling sprayers (backsprayer and shoulder-sprayer). To evaluate the exposure level the water-sensitive papers were used – they were placed on the elements of the workwear and personal protective equipment of operators. It was conclude that the highest exposure concerned the upper limbs (especially forearms) and the chest. Moreover, on the flat crop higher exposure on the liquid spray was observed for the shoulder-sprayer while on the orchard crop the differences between the sprayers in aspect of exposure were insignificant.
***Key words**: plant protection, spraying, personal protective equipment*

OCENA NARAŻENIA OPERATORÓW NA KONTAKT ZE ŚRODKAMI OCHRONY ROŚLIN PODCZAS PRZEPROWADZANIA ZABIEGÓW OPRYSKIWANIA

Streszczenie

Środki ochrony roślin są jednymi z najniebezpieczniejszych substancji w rolniczym środowisku pracy. Aplikacja środków ochrony roślin przy użyciu niesprawnego sprzętu lub nieprawidłową techniką może stanowić zagrożenie dla osoby wykonującej opryskiwanie, dla osób postronnych oraz dla środowiska naturalnego. Celem pracy była ocena narażenia operatora opryskiwacza na kontakt z cieczą roboczą przy wykonywaniu zabiegu opryskiwania. Badania przeprowadzono dla dwóch typów opryskiwaczy ręcznych: plecakowego i biodrowego. Do oceny stopnia narażenia wykorzystano papierki wodoczułe, które umieszczono na elementach odzieży roboczej i środkach ochrony indywidualnej operatora. Wykazano, że największe narażenie na kontakt z cieczą użytkową dotyczyło kończyn górnych (zwłaszcza przedramion) oraz klatki piersiowej. Ponadto wykazano, że podczas zabiegu na uprawie płaskiej większe narażenie na kontakt z cieczą wystąpiło przy użyciu opryskiwacza biodrowego, zaś przy opryskiwaniu uprawy sadowniczej nie stwierdzono istotnego wpływu typu opryskiwacza na pokrycie ciała operatora cieczą użytkową.
***Słowa kluczowe**: ochrona roślin, opryskiwanie, środki ochrony osobistej*

1. Introduction

Nowadays in agriculture, the chemical method is the popular way of the plant protection. Generally, chemical substances of plant protection are applied during the spraying process. In the case of large-area crops the spraying is used by the sprayers (pulled by tractors or self-propelled). In turn, on small-area crops there are use the manual handling sprayers. In this case the operator of the sprayer is exposed to the contact with the spray liquid (the mixture of the plant protection product and the water). Due to the fact that the plant protection products can have toxic or harmful effect, there is reasonable to conduct research in the range of the exposure the operator to the liquid spray [1].

The exposure of the operator to the plant protection products is dependent on different factors such as: the type and the condition of the sprayer [2], operators experience [3], technique of the spraying – especially correct position of the nozzles [4] and the external conditions [5, 2]. The contact of the operator with the plant protection products can be reduced by the personal protection equipment such as the safety uniform, goggles, half-mask, safety shoes, protective gloves and head protection [6, 7]. Unfortunately, the use of personal protective equipment is related to the discomforts, which can caused situations when the operators will avoid safety equipment [3]. Other way to reduce the of operators exposure to the liquid spray is the correct technique of the spraying process [8, 9].

An evaluation of operators to the plant protection products was the subject of scientific research [10, 11]. Am often the assessment was realized using the method based on determination of the masses of drops covering the body parts of operator [12]. This method is known as the most accurate, but there are some difficulties in its use – for this reason, in recent years new method with fluorescent markers is used [13]. In research of the operation parameters of the sprayers the water-sensitive papers are commonly used – they change the colour after the contact with the liquid [14]. Relative low costs and simplicity can caused that this method can be used to the evaluation of the operators exposure to the liquid spray.

Requirements of the safety conditions for the operators of manual handling sprayers cause the necessity of further research in the range of exposure to the spray liquid – these issues were shown in this paper.

The process of chemical plant protection always is related to the exposure of the operator to the contact with liquid spray. In turn, it can caused the immision of the toxic or harmful substances. Especially this problem is important in the case of the manual handling sprayers, because the dis-

tance between the operator and nozzle is smaller than for the sprayers driven by tractors. Due to these facts, following research hypothesis was proposed: the exposure of the sprayer operator on the liquid spray can be different at the some technical variants of the sprayers. For this reason the objection of research was the evaluation of the exposure of sprayer operator on the contact with liquid spray at the operation of spraying on different crops.

2. Methods of research

To research two types of manual handling sprayers were used (Fig. 1):

- Hardii backsprayer; the mass of empty sprayer: 4.0 kg, working capacity: 20 dm3, working pressure: 0.3 MPa, swirl nozzle,
- Flo shoulder-sprayer; the mass of empty sprayer: 1.9 kg, working capacity: 5 dm3, working pressure: 0.3 MPa, swirl nozzle.

a)

b)

Source: own work / Źródło: opracowanie własne

Fig. 1. The sprayers used in research: backpack sprayer (a), shoulder sprayer (b)
Rys. 1. Opryskiwacze użyte w trakcie badań: opryskiwacz plecakowy (a), opryskiwacz biodrowy (b)

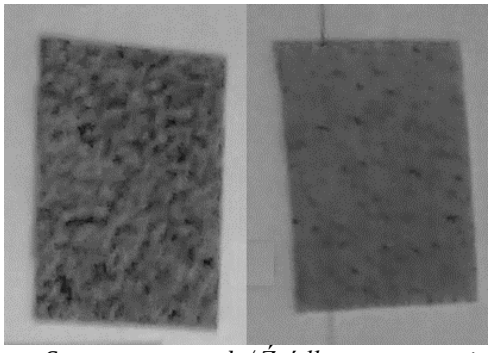
Research was conducted on the field and in orchard conditions. During the experiment the operator was walking with the sprayer on the previously measured section. In the field conditions the spraying was realized by the move of the sprayers lance in the plane parallel to the surface of the field (the distance was equal 0.5 meter). In the case of orchard crop the move of the sprayer lance was realized in the height of trees crowns (in the heights in the range of 1 to 2 meters). The length of the measuring distance was 50 meters, velocity of operator was equal 0.4 meters per second (it was determined based on measurements of the time of whole distance covering). Safety requirements caused that clear water was used as a spray-liquid.

The operators were equipped with the personal protection equipment required at the chemical plant protection processes. The equipment consisted of safety uniform, rubber protective gloves, goggles and half-mask with the A2-class filter. The view of the operator was shown in the Figure 2.

Source: own work / Źródło: opracowanie własne

Fig. 2. The operator with the personal protective equipment
Rys. 2. Operator wyposażony w środki ochrony osobistej

An exposure of the operator to the liquid spray was assess based on the analysis of water-sensitive papers placed on selected points of the operator body. There were used Syngenta water-sensitive papers – after the contact with the water they change their colour from yellow to blue. The views of the papers were shown in the Figure 3.



Source: own work / Źródło: opracowanie własne

Fig. 3. Water-sensitive paper covered by the water
Rys. 3. Papierki wodoczułe pokryte cieczą

Water-sensitive papers were placed on following 11 places on the operator's body (they were partially visible in the Fig. 2):

- head (1 point),
- chest (1 point),
- back – below the neck (1 point),
- left and right shoulder (2 points),
- left and right forearm (2 points),
- left and right thigh (2 points),
- left and right foot (2 points).

To determine the level of coverage of water-sensitive papers the graphically analysis in GIMP (GNU Image Manipulation Program) software was conducted. This software is dedicated to processing of the raster graphics, it was released in The United States by GNU Company. After each passage of the operator the papers were taken from the uniform, then they were scanned and analyzed. The level of coverage was determined according to the equation 1.

$$P_{sp} = 100 \cdot \frac{A_p}{A_c}, \% \quad (1)$$

where:
P_{sp} – level of coverage, %,
A_p – blue surface on the paper (surface covered by the water), cm^2,
A_c – total surface of the paper, cm^2.

Each of measurement was done in tree repetitions – it can allows to calculate mean level of coverage for the papers located in separate point on body of operator.

During the experiment the air temperature was equal 21°C, relative humidity was 47%, there were small clouds without rain. The wind velocity was measured using anemometer was equal 0.6 ms-1.

Obtained results were verified by statistical analysis conducted in Statistica 12.5 software. As a first the test of normal distribution (Shapiro-Wilk) was done, then the test of variance homogenity (Levene) was conducted. Finally, the analysis of variance at significance level $\alpha = 0.05$ was conducted.

3. Results

According to the research scheme the level of coverage of the water-sensitive papers was determined – it should reflected real coverage of the operator body by the liquid spray. Figure 4 presents the values of coverage of water-sensitive papers at the spraying of the flat crop (field conditions).

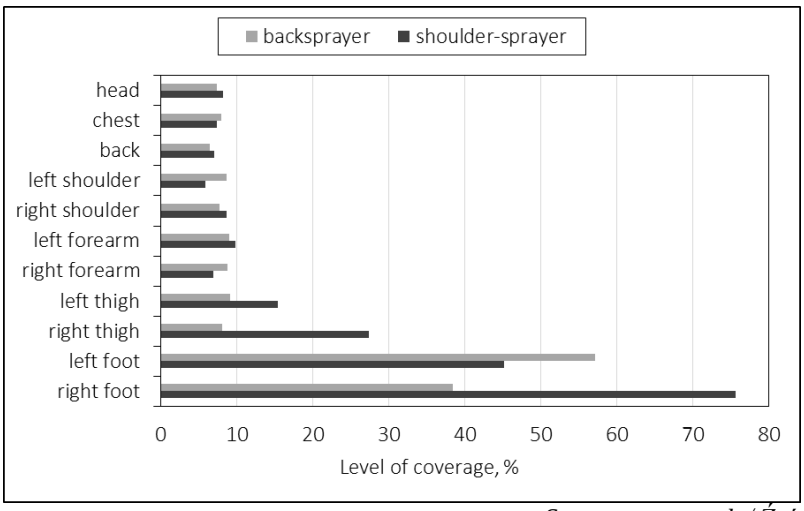
Based on above figure allows to stet that in the case of the backsprayer the lowest coverage concerned the feet. For left foot level of coverage was equal 38.5%, while for right foot it reached 57%. This situation was caused by characteristics of the sprayer work – the nozzle was dislocated in the small distance from the surface. Moreover the drops were drifted to the feet by apparent wind phenomenon. Relatively high difference in the coverages for left and right foot resulted from the sprayer design. The hose with the lance equipped with nozzle was mounted on the right side of the sprayer which required holding of the lance in the right hand. For those reason right side of the body was expose to the liquid spray more than left side. In the case of other parts of body the coverage level was relatively low (it was not exceed 10%).

Analysis of the coverage at the use of shoulder-sprayer allows to determine some differences in comparison to the backsprayer. The highest values of analyzed parameter were observed for the water-sensitive papers located on the feet (46.4% for the left foot and 76.1% for the right foot). For the papers located on the thighs the coverage was higher than for the backsprayer – they were equal 15.4% and 27.8% for left and right side, respectively. For other body parts values of coverage level did not exceed 10%.

The differences in coverage for both types of sprayers could be caused by different design of the sprayers. In the shoulder-sprayer the length of the hose was lower than in backsprayer – it resulted in shorter distance between the nozzle and operator. For this reason the body of operator of shoulder-sprayer was more expose to the drops.

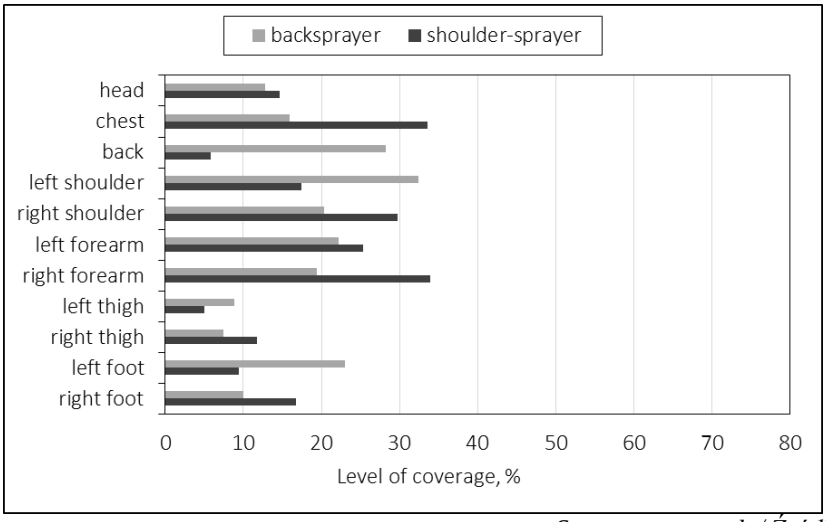
Fig. 5 shows the coverage levels during the spraying in the orchard conditions.

At the spraying of the orchard using the backsprayer the highest value of the coverage (31.9%) was observed for the paper located on the right shoulder. Slightly lower value (28.0%) was observed for the measure point located on the back of operator. In the contrast to the results obtained for the flat crop, in the most of measuring points the level of coverage was higher than 10%. Relatively high values of coverage for right shoulder and both forearms can be explained by character of the spraying in the orchard conditions – the nozzle was periodically lifted over the line of the shoulder. It could caused higher coverage of upper body parts (especially with addition of the apparent wind phenomenon). As in the case of the flat crop spraying, there was a tendence to obtaining of higher coverage of the right side of the operator's body which was related to the design of the sprayer (the hose with the lance was mounted on the right side).



Source: own work / Źródło: opracowanie własne

Fig. 4. Level of coverage of body parts during the spraying of flat crop
Rys. 4. Stopień pokrycia części ciała w trakcie opryskiwania uprawy płaskiej



Source: own work / Źródło: opracowanie własne

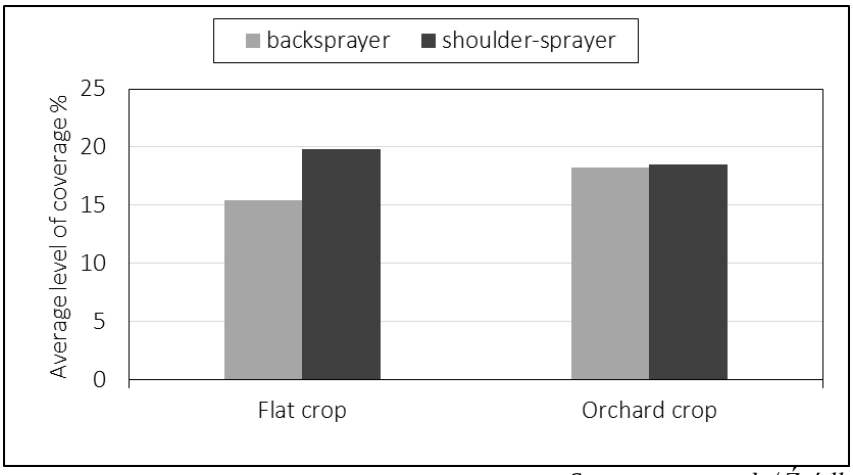
Fig. 5. Level of coverage of body parts during the spraying of orchard crop
Rys. 5. Stopień pokrycia części ciała w trakcie opryskiwania uprawy sadowniczej

Some doubts can concern the differences in the coverages of the papers located on the head (12.6%) and on the back (28.2%) – probably, high coverage in the case of the back was caused by delayed fall of the excess liquid from the crown of threes. The analysis of results obtained for the shoulder-sprayer allows to conclude that the highest coverage was observed for the chest and right forearm (about 34% each). Slightly lower values of coverage level was observed for right shoulder (29.8%) and for left forearm (25.7%). The lowest value of the coverage was obtained for the left thigh and back (below 7%). High values of coverage for right forearm and shoulder were probably due to the fact that the operator held the lance in the right hand while the lenght of the lance was smaller than in the backsprayer; the operating pressure was also lower. These two factors could caused shorter time of persistence of the drops in the air and fast fall on the right upper limb (in comparison to the back-sprayer).

To compare the both sprayers in aspect of acting on the operator, the average values of the coverage were calculated (for all measuring points) – they were presented in Fig. 6.

According to the Figure 6 in the case of the flat crop higher coverage was observed for the shoulder-sprayer - the average value was equal 19.8% while for the second sprayer it was slightly higher than 15%. This situation was probably caused by the differences in design of both sprayers – shorter hose with the lance caused smaller distance between the nozzle and operator's body. Comparison of obtained values of the coverage for the orchard crop allows to observe the lack of the differences in averages of analyzed parameter, while in Figure 5 it is visible that the differences in the coverage for individual body parts were observed on different heights. The comparison of both crops in aspect of the operator's safety allows to conclude that the backsprayer created less exposure during spraying of the flat crop – level of coverage was smaller by 3 percentage points which was over 18%). For the shoulder-sprayer, safer conditions were observed at the spraying of orchard crop (coverage was lower by 1,3 percentage point, which was equal 7%).

The results were statistically analyzed – the effects were presented in Table 1. Presented p-values mean the probability level of acceptance of hypothesis about a lack of influence of the factor. If p-value is smaller than significance level α the factor is statistically significant for analyzed parameter.



Source: own work / Źródło: opracowanie własne

Fig. 6. Average values of coverage level for whole body of operator
Rys. 6. Średnie wartości stopnia pokrycia dla całego ciała operatora

Table 1. Results of statistical analysis
Tab. 1. Wyniki analizy statystycznej

Factor	Value of testing function, F	Level of probability, p	Mean	LSD
Sprayer	13.935	0.0047	backpack sprayer: 16.18	1.60[1]
			shoulder sprayer: 18.82	
Crop	0.012	0.9903	flat crop: 17.48	1.58[2]
			orchard crop: 17.51	

$\alpha = 0{,}05$, [1] – significant , [2] – insignificant

Source: own work / Źródło: opracowanie własne

Analysis of the table 1 allows to conclude that the type of the sprayer as the significant factor for the analyzed parameter, while the type of the crop was insignificant factor.

Obtained results are partially in line with results presented in the literature. High values of coverage of the water-sensitive papers located on the lower limbs (especially at the spraying of flat crop) are in compliance with the results obtained by Nuytens et al. [15] and by Cao et al. [16] (in these papers the results for flat crops were presented). A slightly different tendency was shown in the results obtained by Macher et al. [17] – in this case the hands are described as the most expose body part to the liquid spray. In turn, the results presented by Choi et al. [18] can conclude that at the spraying of high crops relatively high exposure concerned the back. This tendence was not confirmed in the research presented in currently paper. Probably, it resulted from different features of the liquids used in experiments or from differences in the design of the sprayers. High values of the coverage of the chest during the spraying in orchard crops are in accordance with the results presented by An et al. [19] and Cao et al. [16].

4. Conclusions

1. The type of the sprayer is significant factor for the exposure of operator on the liquid spray. On the flat crop, the higher values of analyzed parameter were observed for the shoulder-sprayer. In the case of orchard crop the influence of the sprayer type was smaller than in the flat crop.

2. During the spraying of flat crop the highest coverage of the liquid spray was observed for the feet and thighs. In the orchard conditions the greatest exposure to the liquid spray was observed for the shoulder and forearms.

3. For the backsprayer safer conditions of work were observed in the case of flat crop – in these conditions there was smaller exposure of the operator to the liquid spray. In the case of shoulder-sprayer the better conditions of use were observed during the spraying of orchard crop.

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