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UNEVENNESS OF COVERAGE OF THE SPRAYED OBJECTS WITH THE SELECTED SINGLE- AND DOUBLE-STREAM NOZZLES

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ABSTRACT

The paper presents the results of studies on uneven coverage of sprayed objects using single- and double-stream nozzles. Studies were conducted in laboratory conditions, using a nozzle carrier. To facilitate the interpretation of the study results on uneven coverage and to demonstrate the existing relations, the authors used an indicator of the average degree of coverage of sprayed objects, which is a relation of cumulative coverage of particular sprayed objects to the number of these objects. Although the same experimental conditions for all studied nozzles were used the obtained results of the average degree of coverage and uneven coverage were characterised by considerable differences for particular nozzles. The analysis of the study results did not reveal the existence of the direct dependence between the average degree of coverage of the sprayed objects and the coefficient of coverage uniformity. Both in case of single- and double-stream nozzles, the ones in case of which the lowest and highest average coverage was reporte , were characterised by a similar coefficient of uneven coverage.

Introduction

Effectiveness of the spraying procedure depends, inter alia, on the degree and uniformity of liquid spray application as well as on the uniformity of liquid precipitation and the coverage degree of sprayed surfaces (Godyń et al., 2010). The quality of spraying is largely affected by the applied nozzles. Given the wide range of nozzles on the market, farmers have difficulties choosing the right type and size to get the right effect of a treatment. Every quality analysis of work available on the market of nozzles therefore makes this choice easier. Most of all, selection of the right criterion for assessment of the spraying quality is not only a practical, but also a scientific problem.

One of the indicators characterising the quality of procedure, and thus the proper operation of the applied equipment, is the indicator of the transverse non-uniformity of the spray liquid distribution / liquid spray precipitation. The least complicated procedure of assessment of nozzles operation is conducted during attestation of a sprayer, among others, determining the transverse unevenness indicator (CV). According to the Polish regulations on the requirements for the field sprayers, the value of the coefficient of variation CV% should not be greater than 10% (Szewczyk, 2010; Ch. MRiRW).

Literature includes reports of possible automation of this process (Lodwik and Pietrzyk, 2013a). Such solutions would greatly facilitate operation of the sprayer control station. The solutions used so far to assess the transverse distribution of liquid on the sprayed surface are, however, quite expensive, therefore experiments use the method of photography and the computer image analysis (Lodwik and Pietrzyk, 2013b).

Liquid distribution under nozzles depends on many factors and conditions of liquid spraying. According to Koszel and Sawa (2006) the liquid distribution assessment index under the nozzle depends on the wear condition of a nozzle. Measurement of the liquid flow of a single nozzle in the time unit compared to the nozzle's manufacturer data (nominal expense) indicates the wear condition of nozzles (Koszel and Sawa, 2006; Koszel and Hanusz, 2008; Koszel, 2009). Also important during the liquid precipitation on the sprayed objects is the spraying velocity, direction and wind power (Szewczyk and Wilczok, 2008; Szewczyk and Łuczycka, 2010).

A method of comparing the quality of nozzles operation with the use of assessment of the coverage degree of the sprayed objects is more sophisticated and advanced, because in this method you can also take into consideration the conditions during spraying, both in the laboratory and in field conditions. The objects covering quality can be determined with a chemical method of transferring the traces of droplets after spraying with Miedzian 50WP fungicide from leaves to paper and classifying the obtained images in the scale from 0-400 (where 400 means the leaves covered very well) (Wachowiak and Kierzek, 2007; Kierzek and Wachowiak, 2009). The coverage degree is expressed in percentage and is defined as the relation of the surface covered with liquid to the total surface area to be measured. This ration indicates what part of the protected object is in direct contact with the sprayed liquid (Hołownicki et al., 2002; Lipiński et al., 2007; Godyń et al., 2008; Szewczyk et al., 2012). Both the coverage degree and application of liquid spray may be useful for comparative purposes – for assessing the changes in the spraying technique, verification of the selected parameters of operation of the sprayer and assessment of nozzles operation depending on technical and technological factors (Hołownicki et al., 2002; Derksen et al., 2006; Szewczyk et al., 2012). Research results show that there is a correlation between the coverage degree and the biological efficacy. According to some researchers, the satisfactory effectiveness (for most p.p.m.) in the control of pests is provided by 30% degree of coverage with spray liquid (Hołownicki et al., 2002). However, the studies do not clearly show whether this value applies to the average calculated coverage degree taking into account all components of the sprayed plants and in relation to which pesticides this degree of coverage should apply – with the systemic or contact effect.

The efficiency of plant protection procedures in areas such as: biological efficacy, the use of spray liquid and economic balance, according to many experts in this field, depends mainly on the implementation technique. Labels of p.p.m. contain little information about the application technique. There is no comprehensive technical and utility information on nozzles, which can result in fatal improper use of p.p.m. According to Czaczyk (2013) operators' and consultants' ability to professionally chooose parameters for spraying liquid based on the support information developed in the accessible form is significant. High skills and awareness of effects thanks to the use of modern equipment advantages allow using lower doses of spray liquid and preparations in the given conditions without the risk of failure. Conscious and professional selection of the optimal spray according to the needs of the treatment conditions should result in production of the greatest volume of spray liquid in the form of the most desired fraction of sprayed droplets.

However, according to the authors, the presented indicators do not allow a full assessment of the spraying quality. They can only serve as basic parameters for comparing the equipment applied in the procedure and its accessories of different types and kinds of nozzles. Contrary, additional information for assessment of the spraying procedure can be provided to a sprayer user by such indicators as proposed by the authors – the average coverage of the sprayed objects and the indicator of coverage unevenness of the sprayed objects differently located in relation to the direction of the liquid stream.

Objective of the studies and methodology

The objective of this study was to determine the effect of the type and size of a nozzle on the average coverage degree and unevenness of coverage with sprayed liquid using the selected single- and double-stream nozzles for the fixed flow rate from the nozzles and the spraying speed.

The following nozzles were selected for the studies: single-stream: IDK 12005; DGTJ 11005; AI 11004; IDK 12004; DGTJ 11004; TJ 11003A; AI 11003; DGTJ 11003; IDK 12003 and double-stream: AI 3070-03; AITTJ 11003; HiSpeed 11003; DGTJ 60 11003; CVI TWIN 11003; TJ 60 11003; Lo-Drift 110015 – in the double-nozzle body.

In the studies the following spraying parameters were used:

– dose of liquid $Q=166.8\ l\cdot ha^{-1}$,
– spraying speed $v=2.78\ m\cdot s^{-1}$ ($10\ km\cdot h^{-1}$),
– flow rate from a nozzle $q=1.39\ l\cdot min^{-1}$,
– spraying height $h=0.5$ m,
– liquid pressure p for:
  - nozzles size 03-0.4 MPa,
  - nozzles size 04-0.225 MPa,
  - nozzles size 05-0.145 MPa.

The studies were performed on the test rigs presented in figure 1. The basic element on the presented diagram was the nozzle carrier imitating the sprayer operation. The nozzle carrier consisted of the liquid system, responsible for maintaining the set pressure and the chassis, allowing its passage. The route of the carrier was divided into three parts – run, measurement and final. During the passage on the run line, the carrier obtained the desired speed, then it moved along a 10-meter long measurement line, on which three artificial plants were set in 3-metre spacing. Each plant constituted one iteration. Samplers placed on them in the form of water-sensitive papers were the sprayed objects marked as: horizontal and vertical transverse and longitudinal (fig. 2). The fixed operating speed was set by adopting the appropriate value on the frequency converter, which for the speed of $2.78\ m\cdot s^{-1}$ was 30.7 Hz.

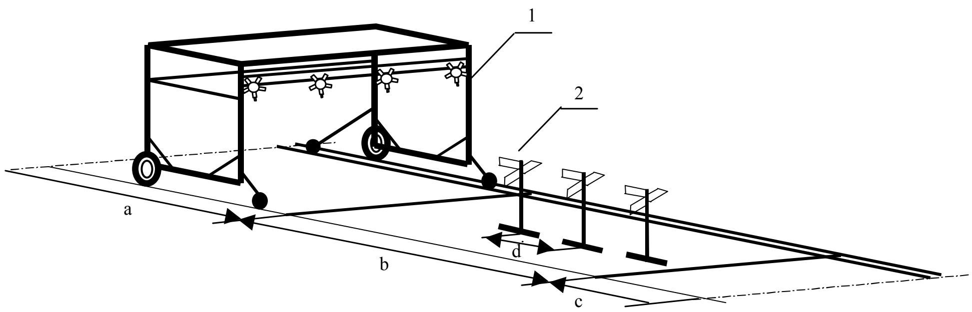

Figure 1. Diagram of test rigs: 1 – carrier of nozzles, 2 – artificial plant, a – run line, b – measurement line, c – final line, d – distance between artificial plants

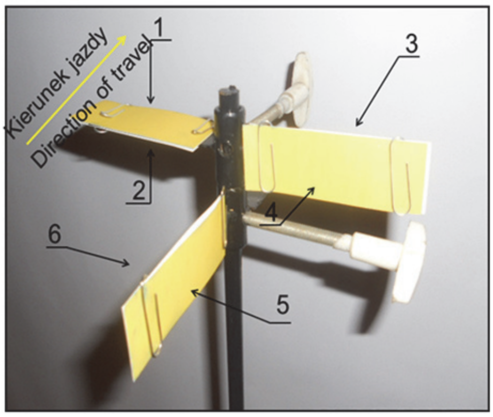

Figure 2. View of artificial plant with marked tested objects: 1– upper horizontal (A_{pog}), 2 – lower level (A_{pod}), 3 – vertical diagonal depart (A_{oj}), 4 – vertical diagonal approach (A_{nj}), 5 – vertical right longitudinal (A_{bp}), 6 – vertical longitudinal left (A_{bl})

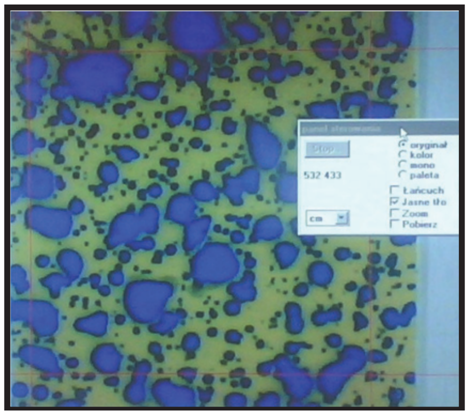

Figure 3. View of analysed sampler

The coverage degree of the sprayed objects was assessed in the Institute of Plant Protection – National Research Institute in Poznan in the laboratory, equipped with a microscope and computer with CSS Video Frame Grabber software. The surface of samplers after contact with the spray liquid changed its colour from yellow to navy blue.

The coverage degree of the sprayed surfaces was determined as the relation of the surface covered with liquid to the remaining one taken into account in the measurement. Sections of a sampler with the dimensions 20x20 mm were taken for analysis in three randomly selected locations. The view of the analysed sampler is presented in figure 3. In order to facilitate the interpretation of the study results of the coverage degree and indication of the existing relations, the authors used the so-called indicator of the average coverage degree of the sprayed objects obtained by summing the coverage degrees of particular sprayed objects and dividing this sum by the number of these objects.

The coefficient of uneven coverage (symbol from the formula) of the sprayed objects was determined by the equation (1) (Gajtkowski, 2000), treating the degree of coverage as the abstract number:

$$\eta = \frac{\sqrt{\frac{1}{n}\sum_{i=1}^{n}(q_i - q_{śr})^2}}{q_{śr}} \quad (-) \qquad (1)$$

where:

q_i – coverage degree of the given object,
$q_{śr}$ – average degree of coverage of the sprayed objects,
n – number of the sprayed objects

Test results

The results of measurements of the average coverage degree for single- and double-stream nozzles are presented in figures 4 and 5, while the indicator of uneven coverage of the sprayed objects – in figures 6 and 7. Since during measurements no traces of coverage of horizontal bottom objects were reported, the results of coverage only for 5 objects were used for further studies. The order of setting the nozzles in the presented graphs has no significance for the comparative purposes, whether in the case of the average degree of coverage, or the indicator of unevenness. The important value of the presented results of studies is to highlight the clear differences in the values of the coverage degree or the uniformity index, which occurred in case of both indicators relating to the studied nozzles.

It should be emphasized here that the conditions of measurements of the studied indicators for all the investigated nozzles were the same. For one-stream nozzles the difference between the smallest and largest value of the average degree of coverage was approximately 8%. While for double-stream nozzles over 11%.

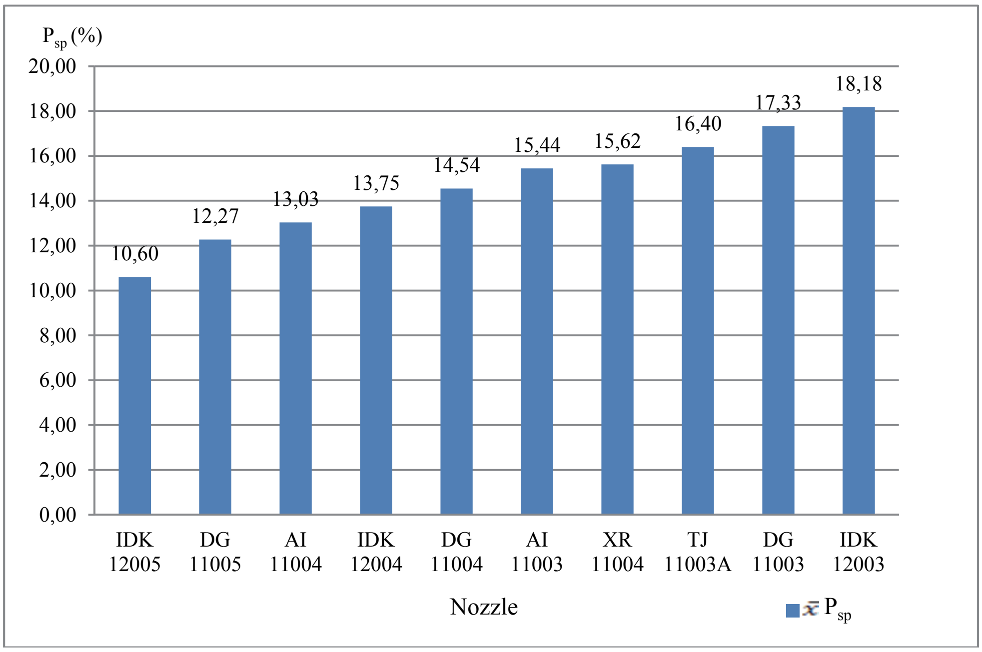

Figure 4. Mean degree of coverage of sprayed objects for single-stream nozzles

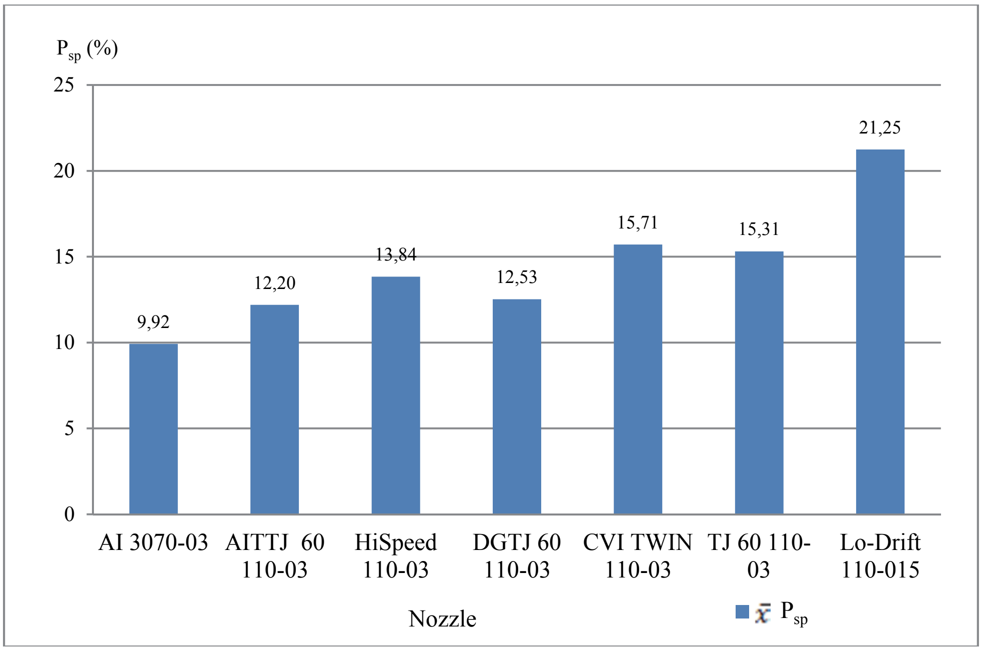

Figure 5. Mean degree of coverage of sprayed objects for double-stream nozzles

In case of double-stream nozzles these results may surprise the specialists, as it could have been expected that two streams of the sprayed liquid should significantly reduce the potential shortcomings of heterogeneity of the liquid stream or the limited ability to cover differently situated sprayed objects. The results of the measurements of the average coverage degree for both studied types of nozzles confirm the known dependency, saying that the greater degree of liquid spraying results in better coverage of the sprayed objects. When, in case of single-stream nozzles, where different sizes of nozzles were selected for tests, the mentioned phenomenon does not evoke any doubts, double-stream nozzles were represented by the same size of nozzles. Their comparison to the Lo-Drift 110015 nozzles placed in the double-stream body clearly indicates that a much better average coverage degree was obtained for the mentioned double-nozzle spraying system.

Analysis of the results of coefficients of uneven coverage of the sprayed objects obtained during the studies leads to similar conclusions, as in case of the average coverage degree. Despite the same conditions of experimentation, the obtained results for particular nozzles are quite different. This applies equally to single- and double-stream nozzles.

The difference between the smallest and largest value of the calculated coefficient of uneven coverage for single-stream nozzles was over 0.30, and in case of double-stream ones – 0.36. In practice, this often means that over one hundred percent differences in the coverage of the sprayed objects occur.

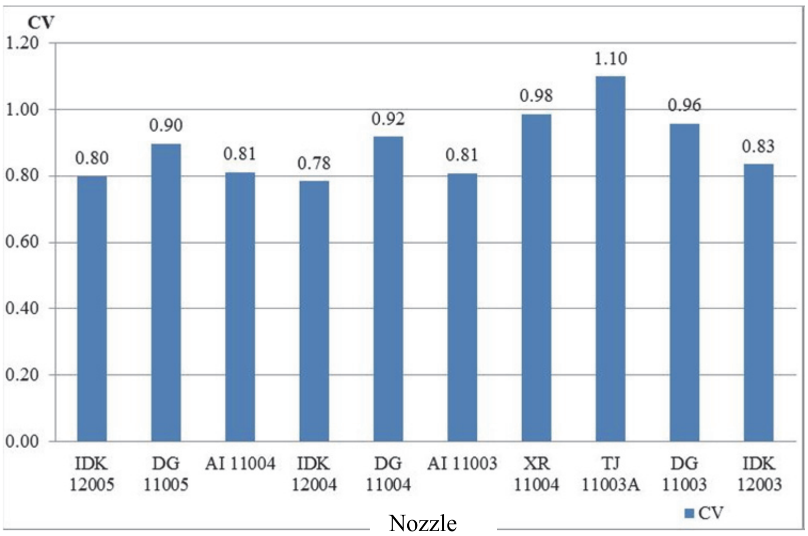

Figure 6. Ratio of coverage unevenness of sprayed objects for one-stream nozzles

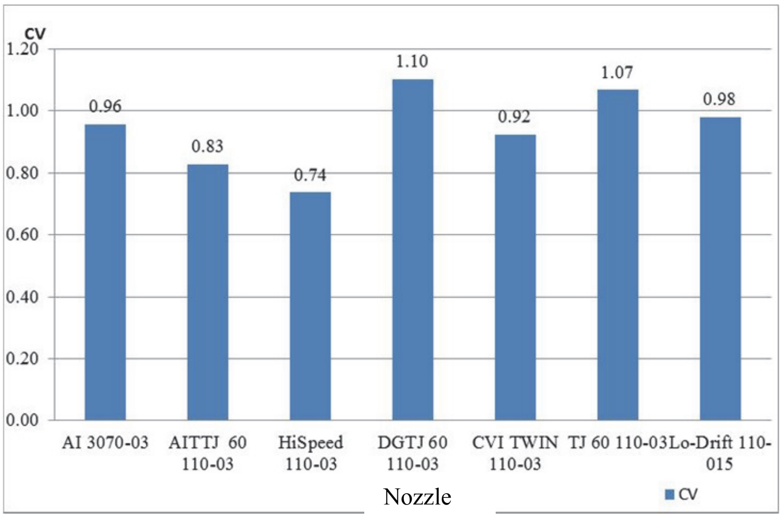

Figure 7. Ratio of coverage unevenness of sprayed objects for double-stream nozzles

There were no dependencies between the average coverage degree and the uneven coverage coefficient. The nozzles, for which the highest average degree of coverage was reported, were not characterised at the same time by the greatest coefficient of unevenness.

Conclusions

During the studies there were not stated any traces of coverage of the objects referred to in the methodology as the horizontal lower surface, both in case of single- and double-stream nozzles. This finding is contrary to the general opinion that double-stream nozzles better cover the underside of a leaf.

The obtained test results and their analysis did not show any direct relationship between the average coverage degree of the sprayed objects and the coefficient of uneven coverage. In case of one-stream nozzles, those nozzles, for which the smallest and largest average coverage was stated, were characterised by a similar coefficient of uniformity of coverage.

The test results using double-stream nozzles of the same size showed great diversity both of the average coverage degree (differences exceeding 100%) and the coefficient of uneven coverage (differences over 30%). A similar phenomenon was observed while comparing the one-stream nozzles of the same size.

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NIERÓWNOMIERNOŚĆ POKRYCIA OPRYSKIWANYCH OBIEKTÓW WYBRANYMI ROZPYLACZAMI JEDNO- I DWUSTRUMIENIOWYMI

Streszczenie. W pracy przedstawiono wyniki badań nierównomierności pokrycia opryskiwanych obiektów przy użyciu rozpylaczy jedno- i dwustrumieniowych. Badania przeprowadzono w warunkach laboratoryjnych, wykorzystując nośnik rozpylaczy. Dla ułatwienia interpretacji wyników badań nierównomierności pokrycia i wykazania istniejących zależności autorzy posłużyli się wskaźnikiem średniego stopnia pokrycia opryskiwanych obiektów, który jest stosunkiem sumarycznego pokrycia poszczególnych opryskiwanych obiektów do ilości tych obiektów. Mimo zastosowania takich samych warunków eksperymentu dla wszystkich badanych rozpylaczy uzyskane wyniki średniego stopnia pokrycia i nierównomierności pokrycia charakteryzowały się dużymi różnicami dla poszczególnych rozpylaczy. Analiza wyników badań nie wykazała istnienia bezpośredniej zależności między średnim stopniem pokrycia opryskiwanych obiektów a współczynnikiem nierównomierności pokrycia. Zarówno w przypadku rozpylaczy jedno-, jak i dwustrumieniowych te, dla których stwierdzono najmniejsze i największe średnie pokrycie, charakteryzowały się podobnym współczynnikiem nierównomierności pokrycia.

Słowa kluczowe: stopień pokrycia, współczynnik, nierównomierności pokrycia, rozpylacz