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Influence of working parameters onto changes in the coefficient of non-uniform transverse liquid distribution

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Abstract: *Influence of working parameters onto changes in the coefficient of non-uniform transverse liquid distribution.* The study presents results of investigation into the coefficient of non-uniform transverse liquid distribution in a sprayer field beam equipped with two-stream atomisers, depending on the height and inclination angle of the field beam and the liquid pressure. The results justify the claim that the most significant impact onto value of the coefficient of non-uniform transverse liquid distribution was that of height of positioning the field beam and its interaction with the angle of inclination of the field beam and liquid pressure. The scope of changes in the coefficient obtained in the investigation was from 3.7 to 18.28% (in the following system: field beam inclination 0–5°, beam positioning height 0.4–0.6 m, liquid pressure 0.2–0.4 MPa).

Key words: coefficient of non-uniform transverse liquid distribution, two-stream atomiser

INTRODUCTION

Changes in agriculture with respect to increasing farm area have been noticeable recently. They result from growing efficiency of machines delivered to the market by sprayers' manufacturers. In the case of sprayers, the easiest way to measure efficiency is to use machines equipped with high capacity containers and wide field beams [Ganzelmeier and Nordmeyer 2008]. Use of wide beams increases the risk of stability loss by the field beam, both in the horizontal and vertical plane. In order to maintain constant liquid deposition onto the area being sprayed as selected due to agrotechnological reasons, the field beam ought to maintain an unchanged distance from the area being sprayed throughout its working width. This requires installation in the field beam suspension mechanisms of special systems for absorbing shocks and limiting the field beam inclination [Anthonis et al. 2005, Lipiński et al. 2011, Kamiński and Kruk 2012]. One ought to emphasise that the investigations completed so far suggest significant impact of horizontal movements of the field beam onto spraying quality [Lardoux et al. 2007a, b]. Efficiency increase may also be achieved by changing the spraying parameters, e.g. increasing the working speed [Gach et al. 1991]. This requires the use of specialist atomisers adapted to work at higher working speeds [Szewczyk et al. 2011]. Atomiser selection is often quite general, but in this case it ought to be based on more extensive data, such as volume of the fraction susceptible to windage (drops under 100 μm) and volume of the ineffective fraction (drop diameter over 350 μm) [Nowakowski 2003, Nuyttens et al. 2009, Czaczyk 2013, 2014]. In such conditions, efficiency of the procedure may be limited and highly dependent on even fall of the liquid onto sprayed surfaces and the degree of coverage [Lipiński et al. 2007a, b, Szewczyk and Łuczycka 2010, Łuczycka et al. 2014].

The ambition to achieve increasingly efficient utilisation of the working liquid has led to development of two-stream atomisers. They are recommended for protection of dense cultures, where high coverage of horizontal and vertical surfaces of the plants subject to spraying is required. The application of this type of atomisers raises the question on how the coefficient of non-uniform transverse liquid distribution is influenced by the working system of the two streams of liquid deflected by a certain angle, in changing working conditions. Thus, the undertaken study was expected to explain interactions between the height and angle of positioning of the field beam and the liquid pressure onto the coefficient of non-uniform transverse liquid distribution for two-stream atomisers. Performance of fundamental investigations provides information regarding the indicators describing spraying quality in relation to the sprayers' working parameters [Lodwik and Pietrzyk 2013].

MATERIAL AND METHODS

The investigation was carried out in laboratory conditions. The investigation station included a suspended sprayer with a pump powered by a continuously variable transmission from an electric motor. The field beam was divided into three sections, powered by a constant pressure control valve. The atomisers were spaced on the field beam at every 0.5 m. New TJ 60 110 06 VS two-stream atomisers were used in the investigation. The atomisers use a system of two streams, deflected from each other at the angle of 60°. The field beam fixing system enabled smooth change of height and angle of positioning.

Measurement of the coefficient of non-uniform transverse liquid distribution was performed using a Hardi Spray Scanner electronic groove table with groove resolution of 100 mm – eight canals 100 mm each, meeting the requirements for testing at sprayer control stations [Nowakowski 2007b, Parafiniuk and Sawa 2011, Parafiniuk et al. 2011]. Instantaneous measurement results were recalculated by the handling programme into the final result expressed as the coefficient of non-uniform transverse liquid distribution [ISO 5682-3]:

$$CV = \frac{\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(V_i - V_{av}\right)^2}}{V_{av}} 100 \qquad (1)$$

where:

CV – coefficient of non-uniform transverse liquid distribution [%];

n – number of measurement grooves on the groove table from the area reached by the stream obtained from atomisers [pcs];

V_i – liquid volume collected from i^{th} groove of the measurement table [m^3];

V_{av} – average volume of liquid per one groove of the measurement table [m^3].

During the investigation, variable parameters were: liquid working pressure, angle of positioning and field beam height above the measurement table. Liquid pressure changes were made in the range from 0.2 to 0.4 MPa, at every 0.05 MPa. Pressure measurements were performed with a TeeJet pressure gauge with the accuracy of 0.01 MPa, within the range of 0–0.5 MPa. Field beam inclination was changed in the range of 0–5°, at every 1°. Field beam inclination measurements were performed with a BOSCH DNM 60L electronic level with the accuracy of 0.1°. The range of field beam height changes above the groove table was from 0.4 to 0.6 m, with changes made at every 0.1 m. The height of field beam positioning above the groove table was measured using a measuring tape with the accuracy of 1 mm. Measurements were performed for a four-metre section of the field beam. Water from the water supply network was used as the working liquid in the measurements; its temperature at the time of measurement was 13–15°C. Ambient parameters during the investigation: temperature 18–21°C, relative humidity 70–96%.

Before commencing the measurement, sample size for the assumed maximum average estimate error was estimated, which was supposed to fall within a prescribed limit. The number of measurements (*N*) was determined based on the initial number of measurements n = 20, for working pressure of 0.3 MPa, field beam angle of 0° and working height of 0.5 m, according to the following relationship:

$$N \geq \frac{t_{\alpha,n-1}^2 \cdot S^2}{\delta^2} \qquad (2)$$

where:
N – number of measurements [pcs];
$t_{\alpha,n-1}$ – t-Student distribution critical value, read for n – 1 measurements and relevance level of $\alpha = 0.05$;
S – standard deviation;
δ – required accuracy.

The calculated number of measurements for the assumed conditions was 2.89. Three repetitions for each combination of variables were assumed in further investigations.

INVESTIGATION RESULTS AND DISCUSSION

In order to determine whether the coefficient of non-uniform transverse liquid distribution differs considerably depend-

TABLE. Variance analysis of factors influencing value of the coefficient of non-uniform transverse liquid distribution

Source of variation	Sum of square values	Number of degrees of freedom	Average square	Statistics value F_{cal}	Level of relevance
Height: *h*	343.47	2	171.73	2083.7	<0.0001
Angle: *k*	650.88	5	130.17	1579.4	<0.0001
Pressure: *p*	62.475	4	15.619	189.51	<0.0001
Interactions					
$h \times k$	922.70	10	92.270	1119.5	<0.0001
$h \times p$	49.166	8	6.1458	74.57	<0.0001
$k \times p$	48.492	20	2.4246	29.42	<0.0001
$h \times k \times p$	14.835	40	0.6211	7.54	<0.0001

ing on the positioning height, field beam inclination angle and fluid working pressure, variance analysis was performed on the investigation results (Table). For all analysed parameters and interactions between them, the analysis demonstrated significant influence.

Analysis of the investigation results allowed statement that the most significant influence onto the coefficient of non-uniform transverse liquid distribution for the analysed two-stream atomiser was that of the field beam positioning height. The most unfavourable operating system of the field beam was observed when the field beam was inclined at the angle of 5° while its positioning height was the lowest of all investigated levels (0.4 m), at the pressure of 0.2 MPa, which then equalled 18.28% (Fig.). Change in the positioning angle of the field beam in the vertical plane involves change in height of particular atomisers placed on the beam, and their asymmetrical positioning towards the vertical surfaces being sprayed. Non-uniform liquid distribution is a serious defect which hinders or prevents reasonable use of atomisers. If the field conditions generate the risk of such inclination of the field beam, then, in case of work at 0.4 m from the sprayed surface, it is possible to increase the working pressure which will reduce the coefficient. Yet, this requires change of the working speed in order to maintain the required dosage of the spraying product. Pressure growth by 0.2 MPa will enable reduction of non-uniformity to the level of 14.96%. However, as demonstrated in the investigation, liquid

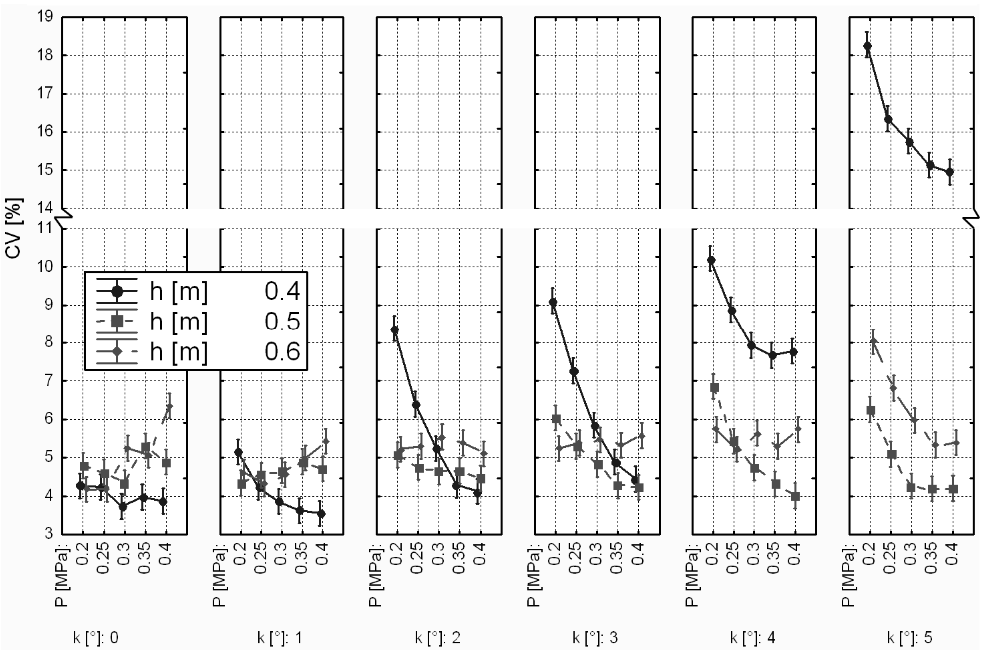

FIGURE. Course of changes in the coefficient of non-uniform transverse liquid distribution (*CV*) depending on working pressure (*p*) and height of field beam positioning (*h*) for the analysed angles of field beam inclination (*k*) pressure growth does not always have favourable influence onto the indicators used for evaluating spraying quality. Moreover, application of higher working pressures involves generation of a higher number of drops susceptible to windage and dangerous to the environment, as well as changed liquid stream parameters [Nowakowski 2005, Szulc and Czaczyk 2013]. As demonstrated by Świechowski et al. [2015], during work of a field beam at the height of 0.5 m, reduction of liquid pressure from 0.3 to 0.15 MPa allowed reduction of the effect of windage by 50%.

For the discussed combination of variables, working height increase by 0.1 to 0.5 m allowed achievement of the coefficient of non-uniform transverse liquid distribution under the required level of 10%. For liquid pressure of 0.2 MPa and field beam inclination angle of 5°, its average value was equal to 6.3%. Another change of the working height by 0.1 to 0.6 m results in increase of the analysed coefficient to 8.03%. Working height increase involves increased risk of windage growth. Change in the working parameters of the field beam, equipped with LU 120-03 gap atomisers, operating at the height of 0.5 m at the pressure of 0.3 MPa, to the height of 0.75 m and pressure of 0.5 MPa, caused windage increase by 270% [Świechowski et al. 2015]. Noticeably, in case of change in the working height of the field beam, there is a certain minimum value of the coefficient of non-uniform transverse liquid distribution at which the most beneficial variant of working parameters is achieved. This is connected with the nominal angle of spraying for individual atomisers which operate on the field beam as a group [Nowakowski and Chlebowski 2008]. Nowakowski [2007a], who analysed operation of a field beam equipped with XR 110 03 flat-stream atomisers at the working heights of 0.4–0.8 m, liquid pressure of 0.2–0.4 MPa and field beam inclination angle of 1–5°, identified the said minimum which occurred for the height of 0.6 m and was equal to 5.56%.

The most beneficial working configuration of the field beam equipped with two-stream atomisers was achieved for a field beam working at the angle of 0 or 1°. In case of liquid pressure changes from 0.2 to 0.4 MPa and changes in the field beam positioning height from 0.4 to 0.6 m, change in the coefficient of non-uniform transverse liquid distribution was from 3.7 to 6.4%. Maintenance of the assumed working parameters allows protective spraying of the plants in compliance with the recommended acceptable coefficient values. This ensures the required application of the active substance onto the objects to be sprayed and reduces hazard to the environment [Szewczyk 2010].

Acquisition of data concerning changes of the coefficient of non-uniform transverse liquid distribution will allow development of a prognostic model regarding operation of the whole field beam [Nowakowski 2006, Parafiniuk and Tarasińska 2013].

CONCLUSIONS

1. From among the analysed technical parameters related to operation of a sprayer equipped with two-stream atomisers, the most significant influence onto the coefficient of non-uni-

form transverse liquid distribution is that of height of the field beam and its interaction with the inclination angle of the field beam and liquid pressure.

2. Value of the coefficient of non-uniform transverse liquid distribution may be reduced by increasing the liquid pressure in case of cooperation with the height and inclination angle of the field beam.
3. Obtained investigation results constitute basis for development of a prognostic model regarding operation of the field beam, which may be used in systems of automatic control of operation of a field sprayer.

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Streszczenie: *Wpływ parametrów roboczych na zmiany wartości współczynnika nierównomierności rozkładu poprzecznego cieczy.* W pracy przedstawiono wyniki badań współczynnika nierównomierności rozkładu poprzecznego cieczy dla belki polowej wyposażonej w rozpylacze dwustrumieniowe w zależności od wysokości i kąta ustawienia belki polowej oraz ciśnienia cieczy. Otrzymane wyniki pozwoliły na stwierdzenie, że największy wpływ na wartość współczynnika nierównomierności rozkładu poprzecznego cieczy miała wysokość ustawienia belki polowej oraz jej interakcja z kątem pochylenia belki polowej i ciśnieniem cieczy. Zakres zmian współczynnika, jaki otrzymano w badaniach, wynosił od 3,7 do 18,28% (w układzie: wychylenie belki polowej 0–5°, wysokość ustawienia belki 0,4–0,6 m i ciśnienie cieczy 0,2–0,4 MPa).

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