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INFLUENCE OF CHOSEN WORKING PARAMETERS OF SPRAYER ON COEFFICIENT OF VARIATION OF TRANSVERSE LIQUID DISTRIBUTION FOR TWIN FAN NOZZLE

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The aim of the work was to evaluate the influence of changes of technical working parameters of a field sprayer on changes of the coefficient of variation for double stream atomisers. The technical parameters were the height and the inclination angle of the sprayer boom and spraying pressure. In the studies, a Drift Guard TwinJet Flat Spray nozzle (DGTJ60 11003 VS) was used. It generated two flat fans of liquid at the spray angle of 110°, directed forward and backward in relation to the direction of sprayer movement. It has a 60° angle between its two fans. The measurement of the coefficient of variation of transverse liquid distribution was done using the Hardi Spray Scanner patternator. The obtained results indicate that the height of field boom setup, the angle of inclination, and their interaction had the strongest influence on the value of the coefficient of variation of transverse liquid distribution for the field boom equipped with the DGTJ60 11003VS nozzle. Field boom setup during the spraying at the height of 0.5–0.6 m, keeping field boom inclination from 0° to 2°, and using the liquid pressure of 0.4 MPa allowed for gaining the lowest values of the coefficient from 5.03% to 6.53%.

Keywords: twinjet flat spray; coefficient of variation; spraying pressure; sprayer boom height

Pesticide treatment is an extremely important and essential issue in the whole plant production cycle. Doing it untimely or in an improper way may result in crops reduction or their loss and may pose a threat for the environment. A lot of technical, technological, environmental, and biological factors have an impact on the final result of spraying. One of the main factors is a choice of a suitable atomiser and maintaining its optimal working conditions.

Using dual stream atomisers or heads which allow for mounting two atomisers at the angle in relation to the head axis is becoming more and more common. As Krawczuk et al. (2021) show, such a solution allows for obtaining the increase in liquid deposition on vertical plant parts. Moreover, it limits excessive liquid deposition on upper plant surfaces which may result in liquid dripping onto the soil and losses of preparation and may cause a threat for the natural habitat. Using dual stream atomisers allows for the increase in treatment efficiency by increasing the working speed without the risk of the decrease in coverage on sprayed surfaces (Sikka et al., 2022; Kulkarni and Deshmukh, 2017). Twin flat fan nozzles create two non-vertical sprays (flat fans), and the angle between them can be symmetrical or asymmetrical. Therefore, they can also decrease the non-vertical spray droplet impact on the leaf surface (Aliverdi and Borghei, 2021; Vallet and Tinet, 2013). The spray angle is an important parameter in the liquid atomisation process. It affects the flow field at the exit of the nozzle, thereby affecting the deposition effect of droplets on the required target (Tanbayev et al., 2023; Altieri and Cryer, 2018; Makhnenko et al., 2021).

Maintaining positive features of dual stream atomisers is possible while keeping assumed working parameters. However, in field conditions, the parameters such as field boom inclination or the change of working height may change as a result of the influence of terrain conditions. Field sprayer boom inclinations and the change of working height, which occur during the work, will cause the increase of the value of the coefficient of spraying variation (Lodwik et al., 2020; Balsari et al., 2019; Manzone et al., 2020). As a result, an excessive drift of liquid may occur which may result in the threat for neighbouring crops (Nowakowski, 2007; Yarpus-Bozdogan and Bozdogan, 2009; Wang et al., 2022, 2023). In the case of such conditions, the effectiveness of the treatment can be limited, and it depends largely on the uniformity of liquid precipitation on sprayed surfaces and on the degree of plant coverage (Świechowski et al., 2015; Roten et al., 2013; Anken et al., 2024; Ochowiak et al., 2020). That is why aiming at more and more effective use of working liquid is connected with constant works on evaluation of the quality of the work of the field boom (Ooms et al., 2003; Parafiniuk and Tarasińska, 2013; Novak et al., 2014). Also, works on constructional solutions aimed at the reduction of unwanted changes of filed boom setup, are being done (Yan et al., 2021; Cui et al., 2018, 2019; Manea et al., 2018).

Therefore, the aim of the undertaken research was to explain the influence of height and the setup of field boom angle and liquid pressure on the value of the coefficient of variation of transverse liquid distribution for the field boom equipped with DGTJ60 11003 VS dual stream atomisers. There is little research on the effects of twin-stream nozzles on the ecological and performance characteristics of agricultural spraying. The tested operational parameters of the sprayer are important for the correct execution of crop protection measure and are quite often overlooked in agricultural practice.

Material and methods

Material

The research was done using brand-new DGTJ-60 11003VS atomisers of the TeeJet company. The tested model of the atomiser is characterised by using a system of two flat streams at the angle of 110°, directed forward and backward in relation to the direction of sprayer movement at the angle of 60° to one another. The nominal flow rate of the nozzles at 0.3 MPa is 1.18 $l \cdot min^{-1}$. The nozzles are not user adjustable.

Research methodology

The tests included in the work were carried out in the Sprayer Research Laboratory of the Faculty of Production Engineering of the Warsaw University of Life Science SGGW with the ISO 16122 (2015) standard. Conducting the research in laboratory conditions allowed for separating measurements from external factors, especially from wind which in this case would have an essential influence on obtained measurement results.

The research stand consisted of a suspended field sprayer with a 300 dm^3 tank, the pump of which was propelled by the variable gear from the electric engine. The sprayer had a working boom of 4.5 m length where atomisers were located every 50 cm, divided into three sections, supplied by a separate valve section. The working pressure for the plume nozzles is 0.25–0.5 MPa. Sprayer pump capacity is 65 ±2 $l \cdot min^{-1}$. The liquid system was steered by the constant pressure valve. The system of mounting the field boom allowed for a smooth regulation of as working parameters (height and inclination angle). Before the tests were carried out, the sprayer's operating parameters were checked.

The tests of the coefficient of variation of transverse liquid distribution were done according to ISO 5682-2 (2017) with the use of the electronic Hardi Spray Scanner patternator. The patternator had 8 drainage grooves, each of which was 100 mm wide, and moved on special rails placed below the field boom. Scanner calibration was done before each series of measurements. The coefficient of variation was calculated according to ISO 5682-3 (2017).

Test conditions

The conducted research concerned defining the influence of chosen working parameters of the sprayer on the value of the coefficient of variation of transverse liquid distribution for the field boom equipped with DGTJ60 11003 VS dual stream atomisers.

Changeable working parameters of the sprayer were:
- liquid working pressure – regulated from 0.2 MPa to 0.4 MPa every 0.1 MPa; the value reading was controlled by the manometer to the nearest 0.01 MPa;
- the height of the boom – changed from 0.4 m to 0.8 m every 0.1 m (height was measured from the surface of the patternator to the atomiser with the measuring tape to the nearest 1 mm);
- inclination angle of the field boom – changed from 0° to 5° every 1° (the measurement of the angle value was done with BOSCH DNM 60L electronic spirit level to the nearest 0.1°).

Clean tap water was used for the tests. For each combination of parameters, three repetitions were done. Therefore, 270 measurements were done in total.

Results and discussion

The test results of the coefficient of variation (CV) of transverse liquid distribution were statistically analysed to check the significance of the influence of tested parameters on its value (Table 1). Moreover, maintaining the orthogonal measuring system allowed for checking the interaction of the height and the angle of field boom work and working pressure on the coefficient of variation (CV).

On the basis of the conducted analysis, it can be stated that the height of the field boom setup, the angle of inclination, and their interaction had the strongest influence on the value of the coefficient of variation of transverse liquid distribution for the tested DGTJ60 11003 VS dual stream atomiser.

For a detailed analysis of the interaction of the chosen working parameters of the sprayer on the value of the coefficient of variation of transverse liquid distribution, the effect of mutual interaction limited to two parameters was presented at first. Such an approach was helpful for analysing and understanding the examined problem in a significant way.

Figure 1 shows the obtained results of the influence of interactions of the inclination angle for the field boom, and for the agrotechnical heights of field boom setup used in treatments on the value of the CV coefficient. It can be observed that for working heights from 0.5 m to 0.8 m the CV coefficient was maintained at the constant level regardless of field boom inclination because the changes were only 2.42% in the range from 5.52% to 7.94%. A decrease in working height to 0.4 m caused a significant increase in the coefficient of variation of transverse liquid distribution, especially for the boom inclination angles of 4° and 5°, respectively, to 10.91% and 26.73%. It can be noticed that as a result of combining extreme tested settings of the field boom (0.4 m), the value of the CV coefficient reaches its maximum. Such a situation is a result of the fact that the ranges of liquid of the obtained stream angle generated by its spraying do not overlap in the lowest point of the field boom setup. However, at the other end of the field boom,

Table 1 The analysis of variation of factors having an influence on the value of the coefficient of variation of transverse liquid distribution for the DGTJ60 11003 VS dual stream atomiser

Source	Sum of squares	*DF*	Mean square	*F*-ratio	p-value
			Changeable parameters		
h: height	947.33	4	236.83	1568.5	<0.0000
k: angle	483.40	5	96.68	640.3	<0.0000
p: pressure	70.72	2	35.36	234.2	<0.0000
			Interactions		
h × k	2213.76	20	110.69	733.1	<0.0000
h × p	4.95	8	0.62	4.1	<0.0002
k × p	16.39	10	1.64	10.9	<0.0000
h × k × p	41.30	40	1.03	6.8	<0.0000
Error	27.18	180	0.15		

DF – degrees of freedom

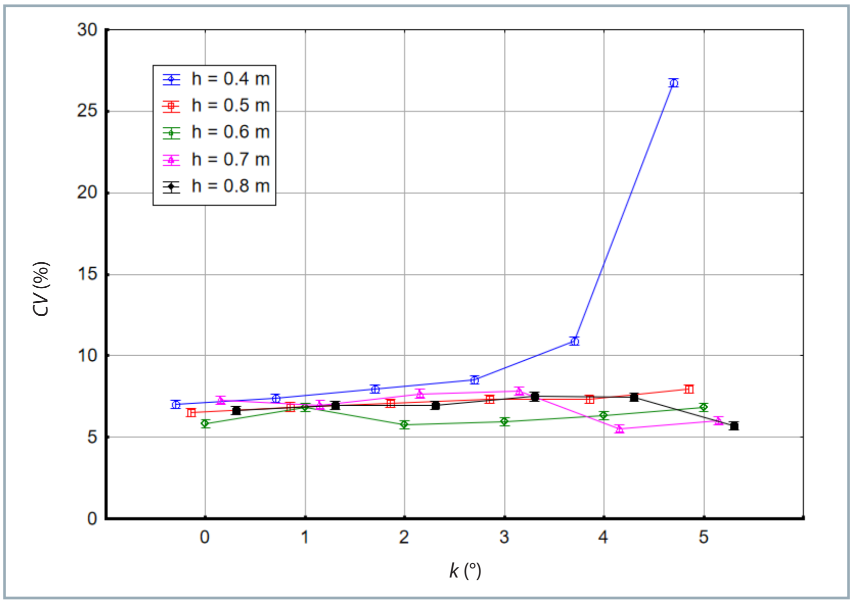

Fig. 1 The course of changes of the coefficient of variation (*CV*) of transverse liquid distribution depending on the inclination angle of the field boom (*k*) for different heights of its setup (*h*)

there is an opposite situation because the ranges generated by the atomiser overlap excessively, causing drifting too much liquid on a narrow area. Such a combination of these variables has an essential influence on producing a bad quality of spraying by leaving an area without spraying in a steady way.

Analysing the course of changes of the coefficient of variation of transverse liquid distribution depending on liquid working pressure for different heights of the field boom setup, the decrease in the value of the CV coefficient with the increase in liquid pressure can be noticed (Fig. 2). Regardless of height on which the field boom is set, the changes of the coefficient of variation are slight and, on average, they equal 1.23%. Such an effect is desirable because the change of liquid pressure, which is necessary to maintain the assumed dose of liquid, should not worsen the quality of spraying. The decrease in the value of the coefficient of variation with the increase of liquid pressure was observed also for one-stream atomisers (Nowakowski, 2007; Višacki et al., 2017). The lowest, i.e. the most favourable value of the coefficient was obtained for the height of the field boom of 0.6 m and on average it was 6.25%.

The interaction of the angle of field boom setup with liquid pressure shows a similar correlation to the height of the boom with liquid pressure (Fig. 3). With the increase of liquid pressure, regardless of the inclination angle of the field boom, the decrease of the value of the coefficient of variation of transverse liquid distribution occurs. On average, for the tested range of variables, the increase in liquid pressure by 0.1 MPa caused the decrease of the CV coefficient by 0.61%. However, the increase in the inclination of the field boom resulted in the increase of the coefficient of variation of transverse liquid distribution. For the range of angles from 0° to 4°, this change was from 6.31% to 8.38%. The highest value was for the angle of 5° with the liquid pressure of 0.2 MPa and it was 11.85%. It is extremely important to maintain the field boom in relation to the spraying surface so that its inclination does not exceed 4° because when this value is higher, the quality of spraying gets rapidly worse.

The analysed results were also developed and compared in an exemplary chart so that the changes of the coefficient of variation of transverse liquid distribution were clear, referring to all possible combinations of variables, for the field boom equipped with the DGTJ60 11003 VS dual-stream atomisers (Fig. 4). The value of the CV coefficient turned out to be the highest (the most unfavourable) in case of the lowest boom setup (0.4 m) and the biggest

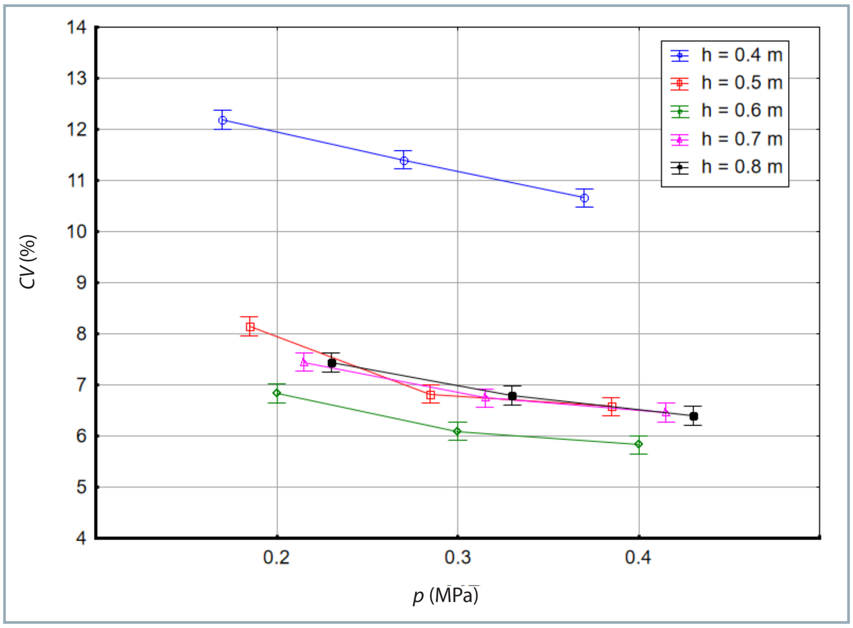

Fig. 2 The course of changes of the coefficient of variation (*CV*) of transverse liquid distribution depending on liquid working pressure (*p*) for different heights of the field boom setup (*h*)

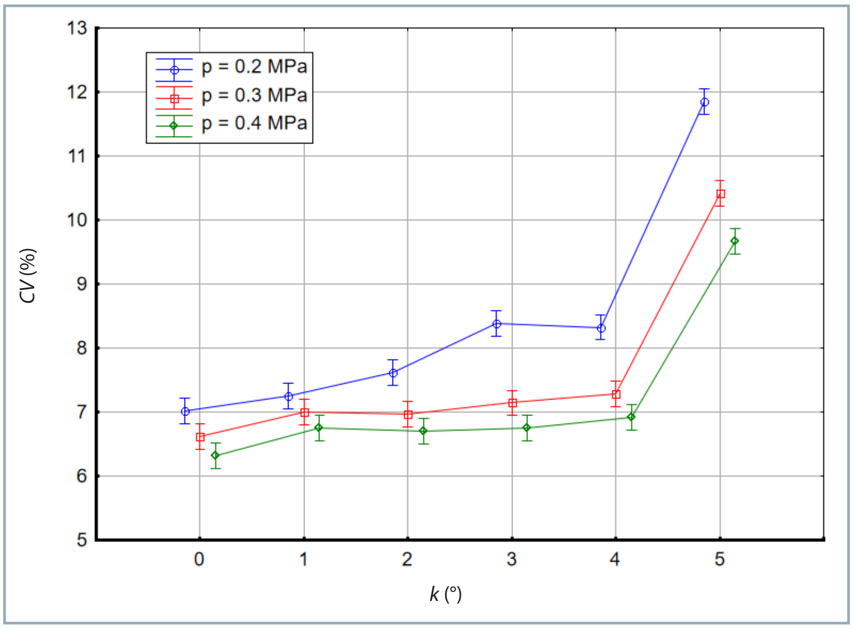

Fig. 3 The course of changes of the coefficient of variation (*CV*) of transverse liquid distribution depending on the inclination angle of the field boom (*k*) for different values of liquid working pressure (*p*)

inclination angle (5°) in combination with the lowest assumed liquid working pressure (0.2 tMPa), and it was 29.55%. In practice, in spite of the possibilities of spraying in the described parameters, such a setup would be a gross mistake. The boom setup in relation to the sprayed surface with such a big inclination angle would be irrational, and the mistake could be detected with the naked eye, which would cause a quick reaction of the operator. However, there is a possibility of the influence of field conditions on the possibility of boom inclination by such a big angle which the operator does not have any influence on. However, it seems that such a case could be only a momentary disturbance due to, for example, the rough terrain occurring on the field. To prevent such situations, the systems of stabilisation and compensation of inclinations which eliminate the influence of the boom inclination are commonly used.

The work with the field boom setup at the height from 0.5 m to 0.8 m does not generate a significant influence on wrong, incorrect spraying. The lowest and at the same time the most favourable value of the coefficient was obtained for the boom height of 0.6 m and the boom inclination angle from 0° to 3°.

Conclusions

1. Based on the statistical analysis of obtained test results, a significant influence of the height of field boom setup, the inclination angle of the field boom, liquid pressure, and their influence on the value of the coefficient of variation of transverse liquid distribution were stated.
2. The height of the field boom setup, the angle of its inclination, and their interaction had the strongest influence on the final value of the coefficient of variation of transverse liquid distribution for the field boom equipped with the DGTJ60 11003 VS atomisers.
3. Maintaining the height of the field boom in the range of 0.5–0.6 m, the inclination of the field boom in the range of 0–2°, and the liquid pressure of 0.4 MPa during the spraying treatment allows for obtaining the lowest

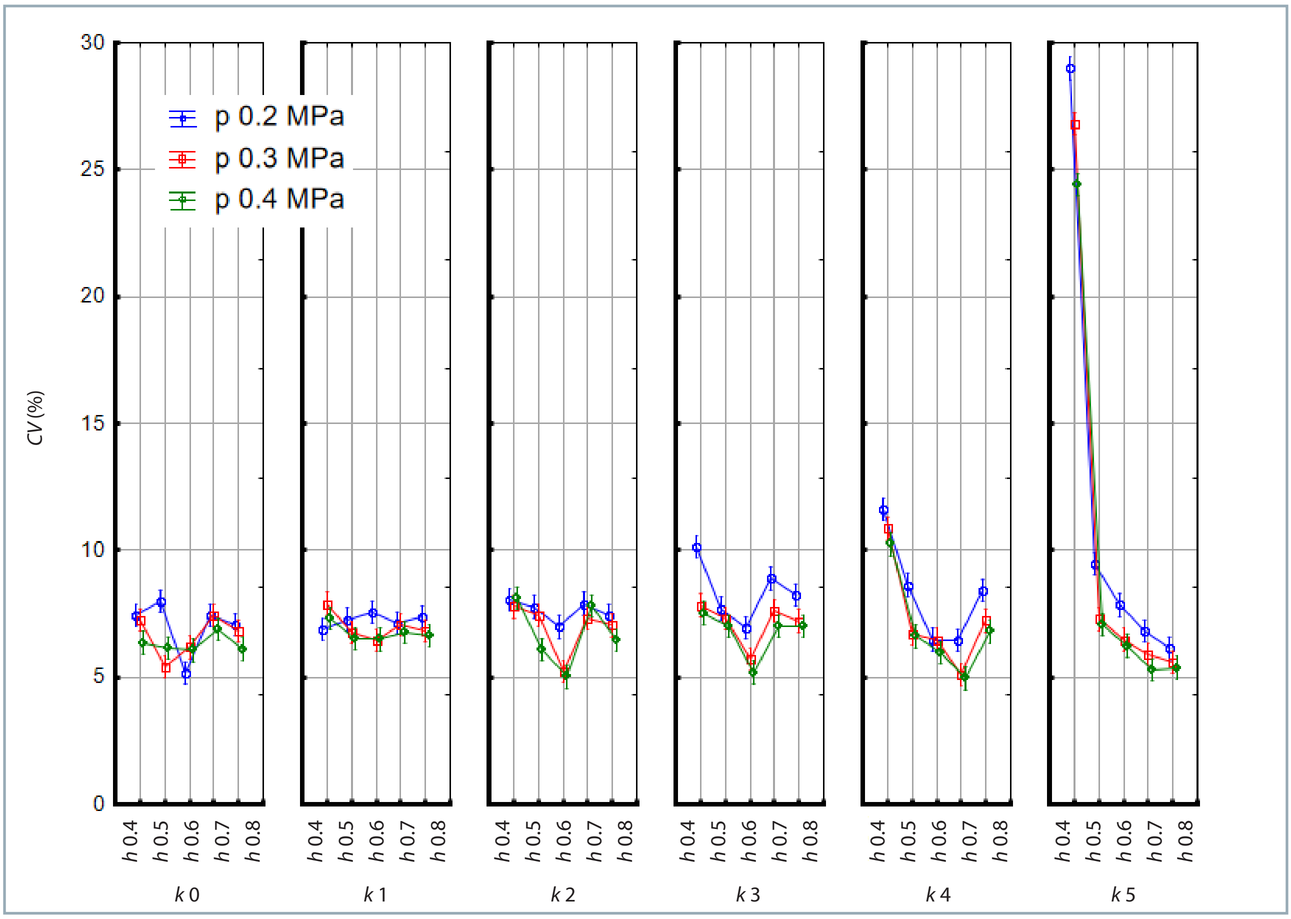

Fig. 4 The course of changes of the coefficient of variation (*CV*) of transverse liquid distribution depending on the heights of the field boom setup (*h*) and liquid working pressure (*p*) for different values of the boom inclination angle (*k*)

values of the coefficient of variation of transverse liquid distribution from 5.03% to 6.53%.

4. Especially the unfavourable value of the coefficient of variation of transverse liquid distribution (28.99%) for the field boom equipped with the DGTJ60 11003 VS atomisers was for the lowest tested height of the field boom of 0.4 m, the highest inclination angle of the field boom of 5°, and for the lowest working pressure of 0.2 MPa.
5. The research carried out showed how important it is to choose the right sprayer' parameter (boom height, boom inclination angle, and working pressure). The results of the research will contribute to the proper execution of agricultural spraying, including a more efficient use of plant protection products, and thus promote the development of sustainable agriculture.

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