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POŁOŻENIE BELKI POLOWEJ OPRYSKIWACZA A ROZKŁAD PRZESTRZENNY ROZPYLONEJ CIECZY I POKRYCIE OPRYSKIWANYCH POWIERZCHNI

IMPACT OF THE POSITION OF THE SPRAYER FIELD BEAM ON THE SPATIAL DISTRIBUTION OF THE SPRAYED LIQUID AND THE DEGREE OF COVERAGE OF THE TREATED SURFACES

W opracowaniu przedstawiono wyniki prac prowadzonych od kilku lat w Instytucie Inżynierii Rolniczej Uniwersytetu Przyrodniczego we Wrocławiu. Celem tych badań było określenie położenia belki polowej opryskiwacza przy zmianie parametrów i warunków pracy. Zmiana ustawienia belki polowej w płaszczyźnie pionowej powoduje zmianę wysokości rozpylania poszczególnych rozpylaczy umieszczonych na belce jak i ich asymetryczne ustawienia w stosunku do opryskiwanych powierzchni pionowych. W związku z tym w wynikach badań przedstawiono również ocenę rozkładu poprzecznego opadu rozpylanej cieczy oraz stopień pokrycia opryskiwanych powierzchni w zależności od ustawienia belki.
Wyniki badań wykazały, że każde wychylenie belki w płaszczyźnie pionowej powoduje zdecydowane pogorszenie jakości opryskiwania określanej przez wskaźnik zmienności rozkładu poprzecznego i stopień pokrycia.
Słowa kluczowe: *belka opryskiwacza, nierównomierność poprzeczna, stopień pokrycia, rozpylacz*

The paper presents the research findings from the studies carried out for a number of years at the Institute of Agricultural Engineering of the Wroclaw University of Environmental and Life Sciences. The aim of the studies was to determine the position of the sprayer field beam when the working parameters and conditions vary. The change of the beam position in the vertical plane results in modifying the spraying height of the particular spray nozzles on the beam. This also leads to their asymmetrical arrangement in relation to the treated vertical surfaces. The research results also include the assessment of the transverse distribution of the sprayed liquid fall and the degree of coverage depending on the beam position.
The results proved that each beam deflection in the vertical plane significantly reduced the spraying quality, which is measured by the variability index of the transverse distribution and the degree of coverage.
Keywords**:** *sprayer beam, transverse roughness, degree of coverage, spray nozzle*

1. Introduction

Chemical plant protection is of particular importance in modern agricultural technologies as it not only helps maintain the yield but also guarantee the effectiveness of investments on the crops, seed material, fertilisation, etc. When this protection is carried out using the technical means such as the sprayers, the treatments must be both efficient and non-harmful to the environment and consumer health (they need to be applied in accordance with valid law regulations).

The quality of the sprayers' work is affected by many technical, technological and climatic factors. The most important are: equipment type, its technical condition, selection of the spray nozzle, suitable parameters of the treatment, temperature, humidity and keeping the recommendations of the pesticide producer. These are the level and uniformity of spreading and a proper degree of coverage that give evidence whether the sprayer works properly [2].

The major reasons for the abnormal distribution of the working liquid are: vibration and movement of the beam caused mainly by the irregularities of the surface. They depend, among other things, on construction solutions of the suspension system. The vertical beam deflection from the ground makes the particular spray nozzles work at different heights and thus the sprayed stream becomes asymmetrical to the plane perpendicular to the surface and parallel to the direction of the aggregate movement (Fig.1) [4, 5]. As a result, the treated surfaces are irregularly covered with the liquid.

The asymmetrical position of the spray nozzles causes that the vertical surfaces are treated as the internal and external in relation to the symmetry axis of the sprayed stream. This also deteriorates working conditions of the spray nozzles, and thus results in irregular coverage.

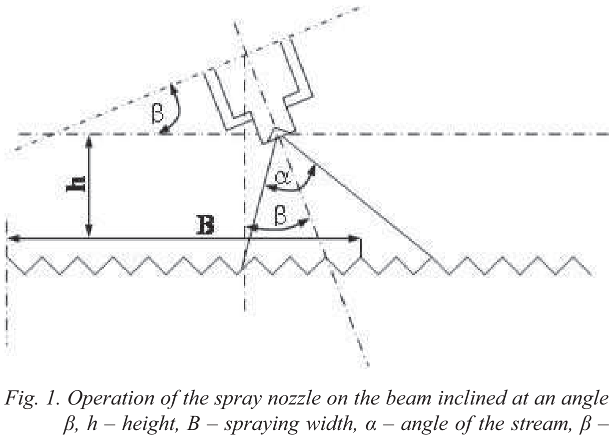

Fig. 1. Operation of the spray nozzle on the beam inclined at an angle β, h – height, B – spraying width, α – angle of the stream, β – asymmetry angle of the spraying

The user of a typical field sprayer cannot do much to affect the technical conditions that determine the beam position during the work as most often the equipment has a specified beam suspension system. However, it is possible to modify the working parameters and choose the working conditions of the sprayer to maintain the beam in the plane close to the horizontal one [3].

The studies on the impact of working parameters on the beam position during the sprayer movement have been conducted at the Institute of Agricultural Engineering of the Wroclaw University of Environmental and Life Sciences for many years. The effect of the spray nozzle position on the spray transverse distribution and the degree of coverage has been also analysed.

2. Aim of the work

The aim of the studies was to:

- assess the position of the sprayer field beam during the movement of the aggregate depending on the working conditions and parameters assumed in this study,
- determine the transverse distribution of the sprayed liquid and the degree of coverage when the spray nozzle, due to the beam deflection in the vertical plane, is asymmetrical to the vertical plane that is parallel to the aggregate movement.

3. Materials and methods

The first stage of the studies was focused on determining the impact of some working parameters of the suspended and attached field sprayers on the beam position during the movement of the aggregate. The effect of the below-mentioned working parameters was also investigated:

- height of the beam position,
- filling ratio of the sprayer tank,
- tractor tyre pressure for the tractor-suspended sprayers and the pressure in the tyres of the attached sprayers,
- working speed.

The suspended sprayers used for testing: PILMET 412 and PILMET 818 vary in the working width, tank capacity and the beam suspension system. The attached sprayers: PILMET 2518, PILMET 2-1018 and PILMET 1014 are mass-produced and they have different beam suspension system.

The measurement sector was marked on the agricultural land and described in the form of the profilogram for both wheels separately. The whole measurement cycle for all parameters took place on the same sector. The beam movements were recorded using a digital camera and its operation was then processed on computer in order to determine the beam inclination angle and the inclination time against the whole working time. To achieve a more general picture of the beam performance during the work, beam position indicator (WPB) was developed as the average inclination angle at which the sprayer is expected to pass through the measurement section. The beam position indicator (WPB) was calculated from the following relationship (1):

$$WPB = \sum_{i=1}^{n} \beta_i \mu_i \qquad (1)$$

where: β – beam inclination angle [deg], μ – part of the area treated at a given inclination angle, n – number of the angle values measured [-].

In order to assess the impact of the significance of the analysed parameters on the WPB, the results achieved were evaluated by multifactorial analysis of variance.

The second part of the studies was aimed at evaluating the effect of the height position and asymmetry angles of the sprayed stream on the transverse distribution and coverage with the spray for some spray nozzles. The spray nozzles were selected from among the main types of nozzles used by Polish farmers.

A constant pressure value of 0,3 MPa was applied for all spray nozzles and the variable parameters of the spray nozzle position were:

- asymmetry angle of the sprayed stream (0 - 4 degrees),
- spraying speed (1,4- 2,5 m*s^{-1}),
- height of the spray nozzle operation (0,4 - 0,8 m),
- spray nozzle type ,
- position of the samplers (vertical inner and outer position and horizontal position).

The studies on the variation index of the transverse distribution were run on a specially constructed stand where it was possible to place the beam and thus the spray nozzle at the desired asymmetry angle and spraying height. The surface to be sprayed was grooved with 50mm grooves. The falling liquid was collected in the graduated cylinders with graduation interval of 2ml. The variation index of the liquid fall was calculated according to the following relationship (2):

$$\eta = \frac{\sqrt{\frac{1}{n}\sum_{i=1}^{n}(q_1 - q_{sr})^2}}{q_{sr}} 100[\%] \qquad (2)$$

where: n- number of the measuring grooves, q_1- liquid volume at the succeeding liquid volume from i-th measuring groove, $q_{śr}$- arithmetic mean of the liquid volume from n-th measuring grooves [1].

Water-sensitive test strips changing their colour under the influence of liquid drops falling down, were applied to evaluate the degree of spray coverage. The range of the colour change determined by a computer programme was treated as a coverage of a particular plant. The way of mounting the samplers to the construction that simulated an artificial plant is shown in Figure 2.

The working speed of the sprayer was simulated by changing the position of an artificial plant with the samplers towards the

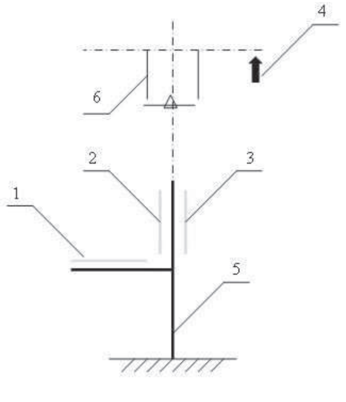

Fig. 2. The way of mounting water-sensitive test strips to the artificial plant: 1 – horizontal sampler, 2 – vertical inner sampler, 3 – vertical outer sampler, 4 – direction of beam inclination, 5 – artificial plant , 6 – spray nozzle under study

sprayer beam. The research results were statistically analysed using a multifactorial variation analysis.

4. Results

Due to the limited volume of the paper, only the most characteristic findings of the measurement results analysis were discussed.

The values of the beam position indicator depending on the studied movement speeds of the attached sprayers is presented in Figure 3 and Figure 4 shows the beam inclination for different air pressure in the tyres. From Figure 3, it appears that increasing the speed causes some deterioration of the beam working conditions by making it more inclined. The problem was more evident for the Pilmet 412 sprayer that has an oscillatory beam suspension system. When analysing the impact of the pressure in the tyres, as seen in Figure 4, the best working conditions for the beam operation were recorded at the pressure of 0,21 MPa and it was even more clear for the higher width. It proves that this parameter is quite important for the sprayer operation.

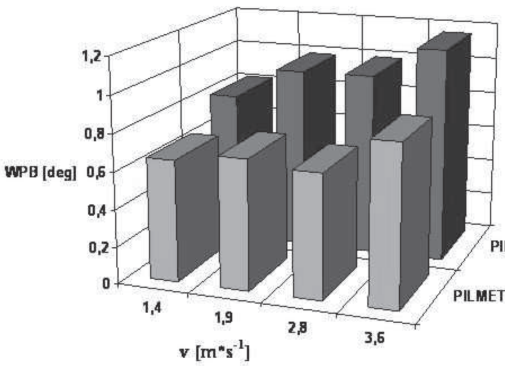

Fig. 3. Impact of the speed (v) on the beam position indicator value (WPB)

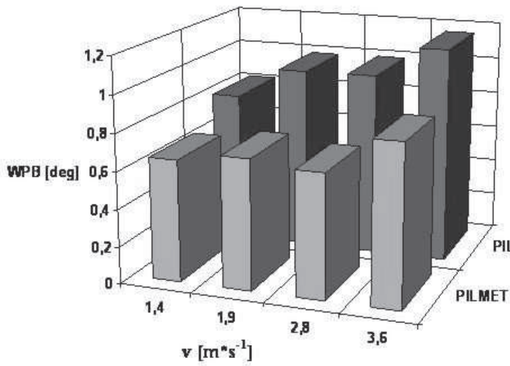

Fig. 4. The value of the beam position indicator at various pressure in the sprayer tyres

The multifactorial variation analysis of the impact of the tank filling ratio and the impact of the beam height on its deflections in the vertical plane turned to the conclusion that these factors are insignificant for the beam position during the work.

Figure 5 presents the average values of the irregularities of the transverse distribution depending on the spraying height at the 95% confidence level.

Using the variation analysis, it was found that the impact of the working height on the irregularities of the transverse distribution of the stream was significant for all tested spray nozzles. However, the effect of the asymmetry angle of the spraying on the spray irregularity tender to be insignificant for the majority of the spray nozzles tested.

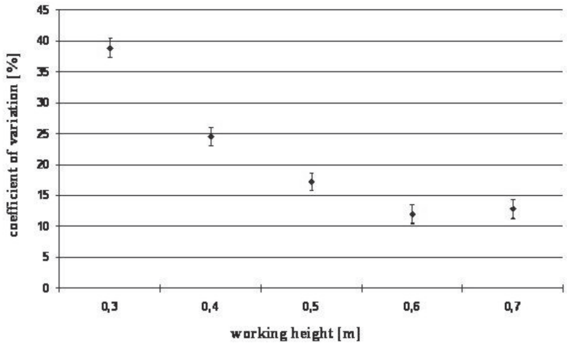

Fig. 5. Average values of the variation coefficient for the tested spraying heights

Figures 6, 7 and 8 show the impact of the height, asymmetry angle of the spraying, sampler speed and its position on the degree of spray coverage for the XR 11003 VK spray nozzle.

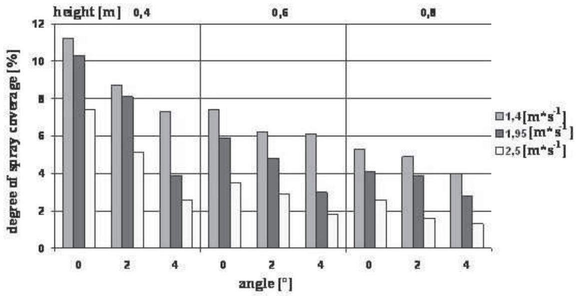

Fig. 6. Degree of spray coverage of the vertical inner sampler

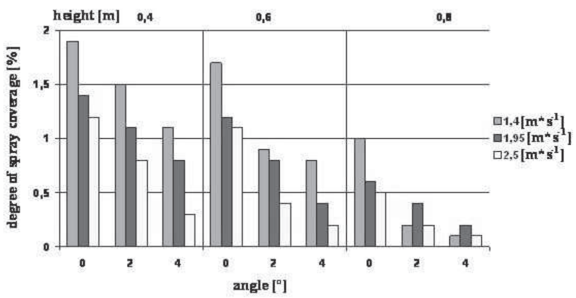

Fig. 7. Degree of spray coverage of the vertical outer sampler

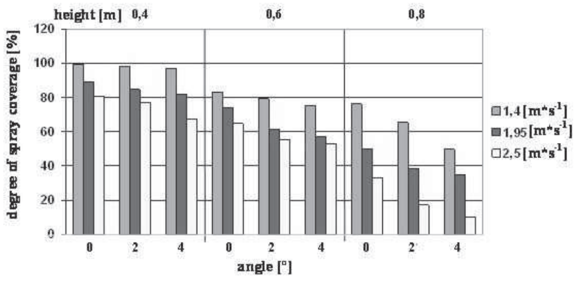

Fig. 8. Degree of spray coverage of the horizontal sampler

Multifactorial variation analysis of the results proved that there was a relation between tested working parameters and the degree of spray coverage of the samplers. The highest impact of the asymmetry angle of spraying on the coverage was noted for the vertical surfaces. Also, the sampler position itself (vertical inner and outer as well as horizontal) had the significant effect on the spray coverage. For the vertical samplers it was found that spray coverage between the inner and outer vertical surface significantly differed.

As indicated on the graphs, there is a considerable impact of the spraying speed on the degree of coverage. It is a logical consequence that at the higher speed and the same spraying pressure, different spraying rate were achieved. It is interesting that worse coverage was recorded for the spraying height of 0,4 m and for other heights: 0,6 and 0,8 m this was less clear. When the beam deflects from the horizontal line, the spraying height is other than recommended and thus the coverage of the treated surfaces seems to be automatically worse. As opposed to the indicator of variation, the impact of the asymmetry angle of spraying on the degree of coverage was clearly distinguished at each spraying height. The schemes show that with the increasing beam deflection, the degree of coverage decreases, and it particularly applies for the vertical surfaces, what in practice can mean the significant deterioration of the spray quality.

5. Conclusions

As regards working parameters of the chosen sprayers, the most significant impact on the field beam deflection was noted for the pressure in the tractor wheels for the suspended sprayers and the pressure in the tyres of the attached sprayers. The second most important factor affecting the beam movement was the aggregate speed but this parameter has a greater effect for the pendulum (for example Pilmet 412M sprayer) than trapeze (Pilmet 818) beam suspension.

The transverse irregularity of the fall was most greatly affected by the working height of the spray nozzles while the asymmetry of their positions tended to be of little significance within the range of asymmetry angles tested.

Sampler position towards the axis of the sprayed stream had a significant impact ($\alpha = 0{,}01$) on the spray coverage degree. For the vertical surfaces it was found that there is a considerable difference in the coverage between the inner and outer vertical surfaces.

Speed of the sampler and the spraying height tended to have the highest impact on the degree of spray coverage for all studied working parameters of the spray nozzles.

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