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THE PROGNOSTIC SIMULATION OF A MOMENTARY DOSE OF LIQUID APPLIED BY FIELD SPRAYER WITHOUT AN AUTOMATIC PRESSURE CONTROL

Summary

The article presents the results of prognostic simulation which refers to the momentary dose of liquid applied by the field sprayer without the automatic pressure control. The data registered at frequency of 1 Hz, related to the speed, the direction of movement and the position coordinates of the sprayer during the process of desiccation of the winter rape were used in the simulation. Based on the results, it was found that during application of chemical protection treatment using a field sprayer without automatic pressure control it is problematic to maintain a constant operating speed and the direction of movement, and as a consequence- entails the coverage of only 25% of the field surface.

Key words: field sprayer, plant protection products, spray, momentary dose

SYMULACJA PROGNOSTYCZNA CHWILOWEJ DAWKI CIECZY APLIKOWANEJ PRZEZ OPRYSKIWACZ POŁOWY BEZ UKŁADU AUTOMATYCZNEJ REGULACJI CIŚNIENIA

Streszczenie

W artykule przedstawiono wyniki symulacji prognostycznej dotyczącej chwilowej dawki cieczy aplikowanej przez opryskiwacz polowy bez automatycznej regulacji ciśnienia. W symulacji wykorzystano zarejestrowane z częstotliwością 1 Hz dane dotyczące prędkości, kierunku ruchu oraz współrzędnych położenia opryskiwacza podczas desykcji rzepaku ozimego. Na podstawie uzyskanych danych stwierdzono, że podczas wykonywania zabiegu ochrony chemicznej z wykorzystaniem opryskiwacza bez automatycznej regulacji ciśnienia, utrzymanie stałej prędkości roboczej oraz kierunku ruchu jest problematyczne, a rezultatem tego jest pokrycie jedynie 25% powierzchni pola założoną ilością cieczy.

Słowa kluczowe: opryskiwacz polowy, środki ochrony roślin, oprysk, dawka chwilowa

1. Introduction

In the vast majority of farms, pest management is performed with usage of pressure tractor sprayers. Most often these machines are mounted or trailed, without automated spray control systems. One of the requirements of high quality spraying is to cover the surface (of the field or plant) with an even layer of chemical agent with drops by nearly the same diameter [1]. The uniformity spraying is particularly important in the application of chemicals at high concentration, because otherwise it may cause local destruction of crops or the ineffectiveness of treatment [2].

Before proceeding to the work and performance of plant protection treatments sprayer should be properly adjusted. The working adjustment is the responsibility of the user, whose main task is to calibrate the working units of the sprayer in order to ensure uniformity of the spraying [3]. The place of starting the treatment should be selected in such way, as to minimize the risk of leaving unsprayed strips and those sprayed twice. It pertains particularly to the bends, which often results in local application of an overdose as well as the lower than recommended doses of plant protection products. To maintain a constant dose of liquid during spraying, a constant operating speed unit of the generator should be kept, and its changes corrected by using only the hand throttle and constantly checking the sprayer operating parameters [4]. It should be noted that if the speed is doubled, to preserve the condition of constant dosage, the pressure must be increased four times [5, 6].

New constructions of sprayers are equipped with the on-board computers that increase the so-called ecological safety. On-board computers used in the field sprayers play the controlling-navigation role, in relation to the working process. Such systems help in reducing operator's errors and simultaneously to control the regulating valves by adjusting the dose depending on the actual speed of the moving generator [7]. According to estimates, almost half exploited sprayers in Poland are older than 10 years. The others, but more recent, were already outdated at the time when they were manufactured and do not meet the basic requirements of modern agriculture [4]. The literature suggests that the movement of the generator during spraying has a large impact on the dose and quality of the applied plant protection product. Deflection of the spray boom in the horizontal plane due to the variable movement of generator resulted in inadequate dose of fluid [8, 9, 10, 11, 12].

According to [13] during performance of plant protection treatment with using modern field sprayer equipped with a control dose of liquid based on the actual speed of the generator, a momentary dose applied by field sprayer during the turning of the generator was variable, and the dose of spray compatible with the assumptions, coated less than half the surface of the field, i.e. 47,6%.

2. The aim of the study

The aim of this study was to assess the overall and individual impact of changes in speed and direction of move-

ment on the value of the momentary dose of spray applied by the field sprayer without the automatic pressure control (classic). The momentary dose for each sprayer was determined based on a prognostic simulation. The simulation used, registered a frequency of 1 Hz, data regarding speed, the direction of movement and the position coordinates of the sprayer during the process of desiccation of the winter rape.

3. Materials and methods

The field study was conducted in the West Pomeranian voivodeship in the county Choszczno, the municipality Choszczno in locality Kołki (53° 07' 46,5" N 15° 37' 42,8" E). The experiment was performed on 7.08.2014 during the process of desiccation of the winter rape in the area of 3,2 ha. On the mentioned plantations during sowing, the technological paths in spacing of 20 m were established. For tests farm tractor John Deere 6620 aggregated with the mounted field sprayer with a working width of 20 m and with 40 nozzles was used. The operator performing the spraying procedure had the appropriate licenses and the sprayer had a current attestation.

For monitoring of sprayer's route recorder consisting of microcontroller, GPS, electronic compass, and specialized software was used. The measuring elements were located on the sprayer boom and overlap the longitudinal axis of symmetry of the machine aggregate. Accuracy of the position measurement was 0,3 m, the speed of 0,1 m·s⁻¹ and the direction of movement 0,1 degrees. Registration of data was made on the SD card.

The data obtained were used for the calculation of the momentary dose of liquid applied by individual sprays while working passes of sprayer. For each sprayer separate calculations were carried out.

The calculation algorithm consisted of the following steps:

— calculations of geographical coordinates of the route

travelled by the symmetry center of sprayer in Cartesian coordinates system,

— calculations of nozzle's coordinates at time t,

— calculations of nozzle's coordinates at time t+dt,

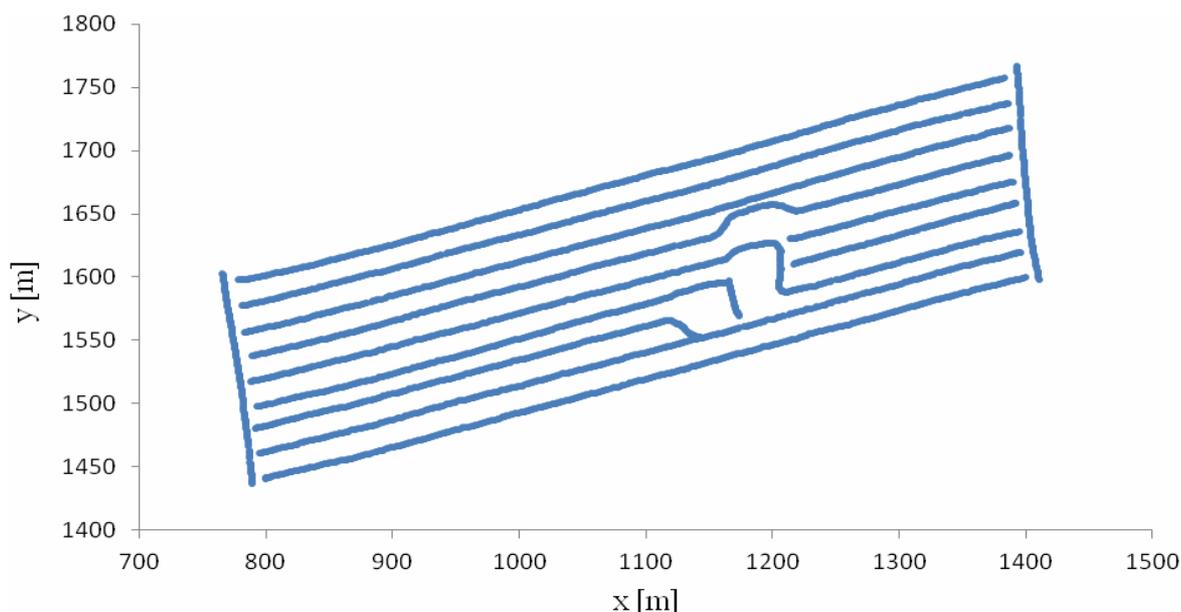
— calculation of the distances travelled by the nozzles at time dt,

— calculations of liquid dose applied by the nozzle in the time dt, with results given as the percentage of the dose on which the sprayer was adjusted.

The results of the obtained calculations of the momentary dose were sorted into 12 compartments. Taking into account the guidelines for the stationary research of sprayers it was assumed that the dose is considered adequate if is contained in the range of 95-105% of the adjustment dose. Other distribution compartment refers to the incorrect doses. In the range from 55 to 155% of the adjusting dose it was assumed the width of the compartments 10%, and two additional compartments containing the results outside the mentioned range. For the calculations Excel 2010 spreadsheet was used, and to illustrate them Statistica 2010.

4. Results

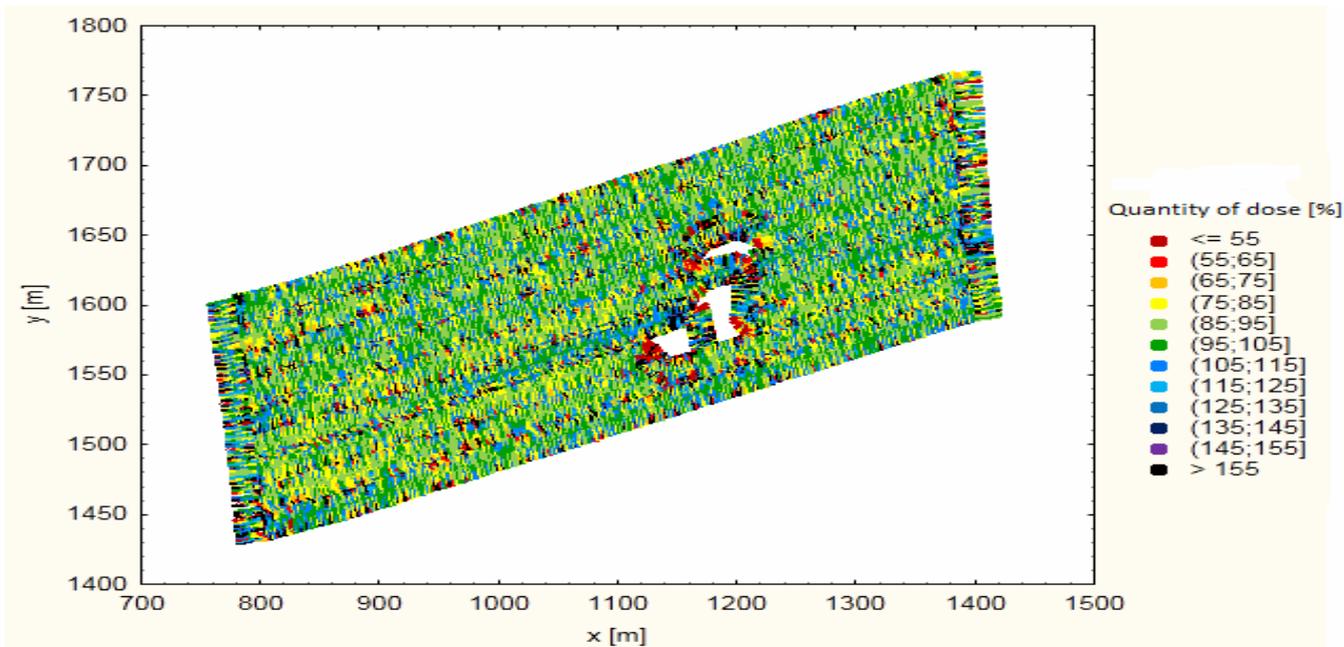
Based on the calculations of the geographical coordinates of the route traveled by the center of symmetry of the sprayer at the coordinates in the Cartesian system, the passage route of the sprayer on the field was determined (Fig. 1). The route contains 3691 points for which the parameters of the sprayer work were collected. Because of the presence of obstacles on the field, some active crossings or their parts were carried out using selected sections of the spray. Based on Fig. 1 it can be concluded, that some of the technology paths, which were established before the sowing were not linear, and the navigation through them resulted in frequent changes of the direction of the movement. Moreover, the distance between the adjacent tracks was not the same.



Source: Own tests / Źródło: Opracowanie własne

Fig. 1. The route of the sprayer during the process of desiccation of the winter rape

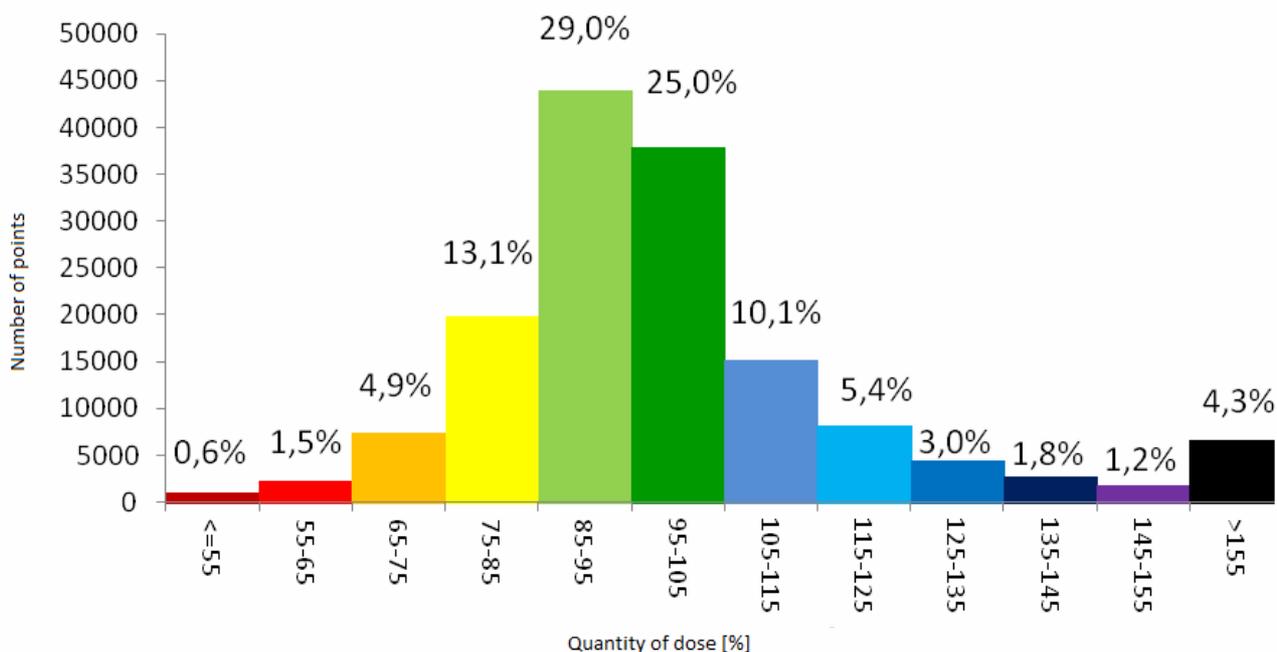
Rys. 1. Trasa przejazdu opryskiwacza podczas wykonywania zabiegu desykacji rzepaku ozimego



Source: Own tests / Źródło: Opracowanie własne

Fig. 2. The areal distribution of the momentary doses of spray made based on the data related to the speed and the direction of the movement of the sprayer

Rys. 2. Rozkład powierzchniowy chwilowych dawek oprysku wykonany na podstawie danych dotyczących prędkości i kierunku ruchu opryskiwacza



Source: Own tests / Źródło: Opracowanie własne

Fig. 3. A histogram of momentary dose of spray created on the basis of the speed and the direction of the sprayer's movement

Rys. 3. Histogram chwilowej dawki oprysku wykonany na podstawie analizy prędkości i kierunku ruchu opryskiwacza polowego

The results regarding momentary dose of spray estimated based on changes in speed of movement of the field sprayer and changes of the direction of movement, is shown in Fig. 2. This chart was prepared on the basis of 151 330 results of calculations of momentary doses. On the enclosed illustration it was observed that the momentary dose of spray is variable over the entire surface of the field, and

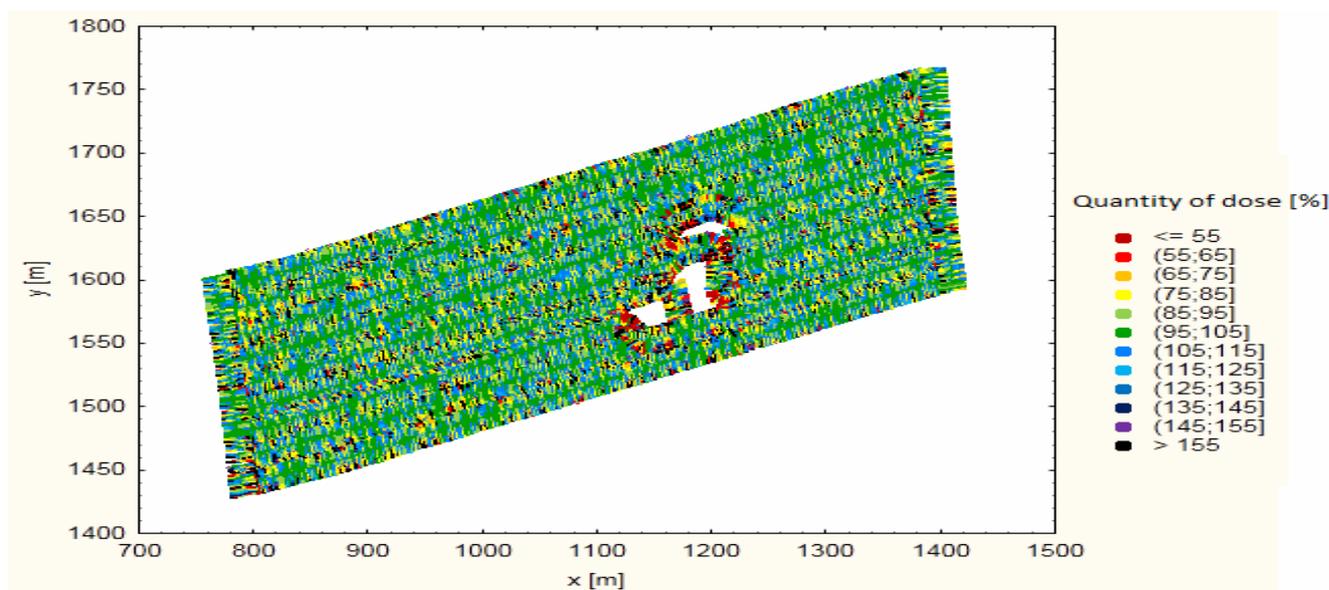
largest differences in the amount of the applied product were recorded in places in which the change of the direction of the movement and speed of the sprayer was forced by the obstacles.

The Fig. 3 shows a histogram of momentary dose of spray calculated on the basis of the data on the speed and the direction of movement of the sprayer. The largest num-

ber of momentary doses (43 957) belonged to range between 85-95% of the regulatory dose, constituting 29,0% of the results for the entire field, and in the case of range for a dose of $\leq 55\%$ occurred 976 observations (0,6%). It was observed a relatively large number of results, i.e. 6556, relating to a dose greater than 155%, which is 4.3% of the total estimated doses. Only 25,0% (37 of 898) of the momentary doses were recorded in the range of 95-105%.

Fig. 4 shows the areal distribution of the momentary dose of spray applied by the field sprayer estimated based on data on the direction of movement of agricultural generator. An independent variable, which describes the value of the momentary dose of liquid, was in this case the value

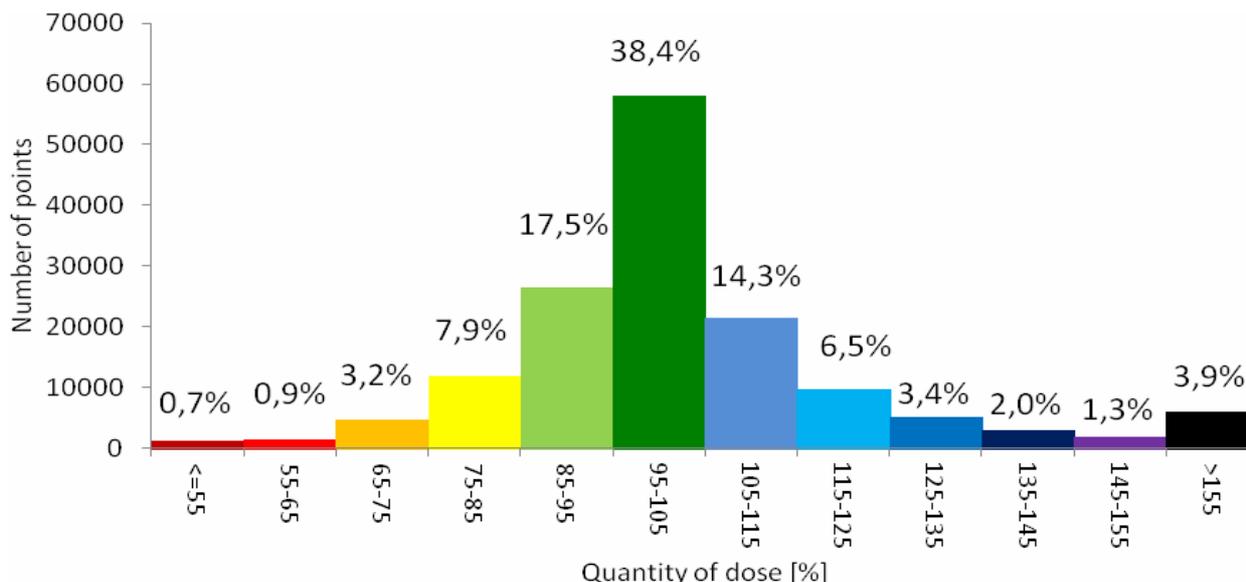
of the angle by which the generator had changed the direction of movement. In the presented analysis it was assumed, that the speed of the movement of the field sprayer on the whole route was the same, and the value of the dose on the axis of symmetry of the sprayer in this case was 100% of nominal value. On the enclosed illustration a plurality of points can be observed, for which the value of dose exceeded 155% of the nominal dose, as well as cases in which the momentary dose did not exceed 55% of the nominal dose. These are mainly places where the operator avoided the obstacles such as ponds and trees. The changes of the direction of movements also occurred during driving the generator along a pre-defined technological path.



Source: Own tests / Źródło: Opracowanie własne

Fig. 4. Areal distribution of the momentary doses of spray applied by field sprayer, created on the basis of the analysis of the direction of the movement

Rys. 4. Rozkład powierzchniowy chwilowych dawek oprysku aplikowanych przez opryskiwacz polowy wykonany na podstawie analizy kierunku jazdy



Source: Own tests / Źródło: Opracowanie własne

Fig. 5. The histogram of the momentary dose of spray created on the basis of the direction of the movement

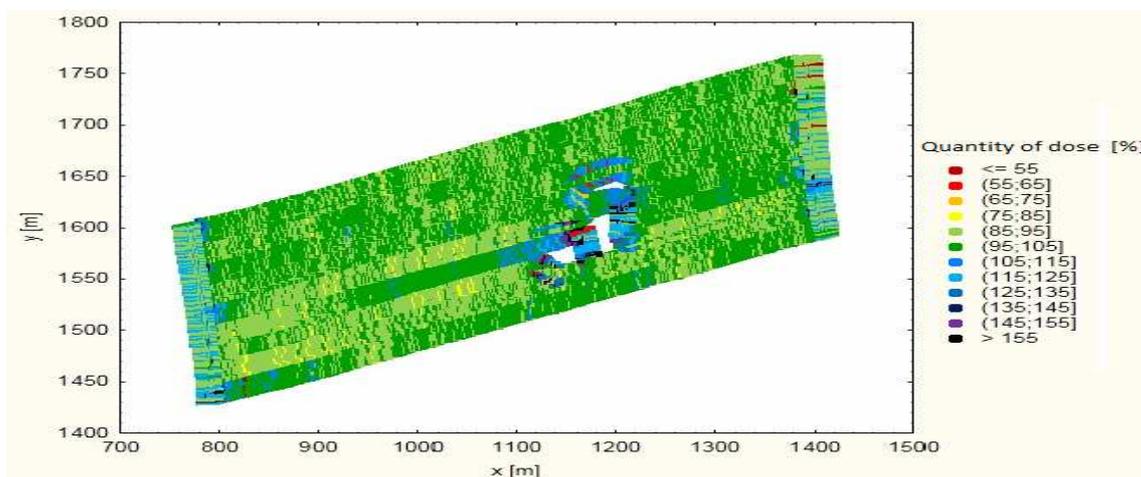
Rys. 5. Histogram chwilowej dawki oprysku wykonany na podstawie analizy kierunku jazdy

Fig. 5 contains a histogram of the momentary dose of spray determined based on the change of the direction of the movement of the field sprayer. The largest number of momentary doses (58 159) belonged to the range of 95-105%, which represents 38.4% of the results for the entire field, and in the case of range for a dose of $\leq 55\%$, 1113 observations occurred (0,7%). A relatively large number of results were observed, i.e. 5929, relating to a dose greater than 155%, which is 3,9% of the total estimated doses. For other results, it should be noted that the value of the momentary dose was diversified, and in the range of 85-115% of the value of the dose, 106274 (70,2%) of measuring points were found.

Fig. 6 presents the values of the momentary dose of spray determined on the basis of data regarding the speed of the sprayer's movement. Operator before starting the procedure had planned the speed of $1,52 \text{ m}\cdot\text{s}^{-1}$. Based on the monitoring of the operating parameters of the sprayer it was found, that the speed of moving of the generator was variable, and its scope was in the range $0,5\text{-}2,5 \text{ m}\cdot\text{s}^{-1}$. Inappropriate speed during the spraying had a negative impact on the 49,3% of the results of the value of the momentary dose of spray. Most unevenly speed occurred in the places where the operator avoided the obstacles resulting from the ter-

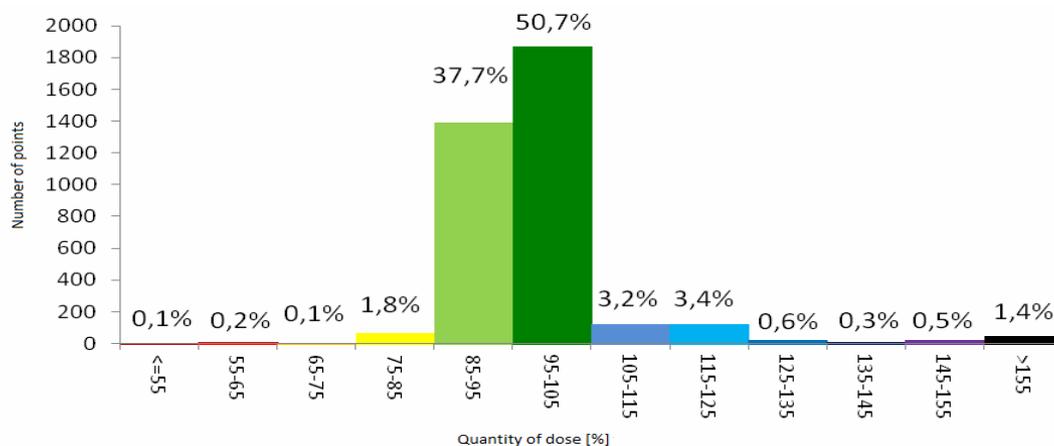
rain. Changes of the speed of the movements were also recorded in a straight line. On the enclosed illustrations, you can see the position in which the momentary dose of spray alternately belonged to the ranges of 85-95% and 95-105%, what indicates on the numerous changes of the agricultural generator's speed of movement After finishing the procedure operator said, that he was not able to maintain the speed of movement of the agricultural generator at the same level at all times of spraying.

The histogram presented in Fig. 7 shows the distribution of momentary dose of spray determined based on the registration the speed of movement of the field sprayer. It was found that more than half of the measuring points (50,7%) were characterized by a proper dose of the plant protection product, it means that the procedure was carried out at the appropriate speed. Too high speed during treatment occurred in 39,9% of measuring points, what resulted in the reduction in dose. Most cases of reduced doses, i.e. 37,7% was observed in the range of 85-95% of the nominal dose. Too low speed of generator was found in 346 measurement points (9,4%), in which the doses of spray amounted to mainly 105-115%, 115-125%, and more than 155% of the nominal dose.



Source: Own tests / Źródło: Opracowanie własne

Fig. 6. Areal distribution of the momentary doses of spray made based on the monitoring of the speed of the field sprayer
Rys. 6. Rozkład powierzchniowy chwilowych dawek oprysku wykonany na podstawie monitoringu prędkości jazdy opryskiwacza polowego



Source: Own tests / Źródło: Opracowanie własne

Fig. 7. The histogram of the momentary dose of spray created on the basis of the monitoring of the speed of the field sprayer
Rys. 7. Histogram chwilowej dawki oprysku wykonany na podstawie monitoringu prędkości jazdy opryskiwacza polowego

To sum up it should be underlined, that carried out studies were made on the basis of the operating parameters of the field sprayer without an automatic pressure control. On the Polish market, this type of sprayers appears in most farms. Lack of control of operating parameters of the sprayer during spraying, especially during changes in the direction of movement (eg. over obstacles) and the changes in speed, causes the operator is not aware of an overdose, or abatement of the dose of the spray. In a conversation with the operator it was stated, that during application of plant protection products, maintaining a constant speed and the direction of movement is onerous, and in some cases, mainly relating to avoidance the obstacles, is not even possible.

5. Conclusions

On the basis of the studies of the process of chemical protection of plants carried out by a trained operator using the sprayer without automatic pressure control system, the following conclusions were enunciated:

1. The appropriate dose of the spray, which differs from the regulatory value for no more than 5%, occurred only in about 25% of the measuring points.
2. Improper dose of spray which resulted from non-rectilinear movement of the generator was found in about 62% of measurement points, and due to inadequate speed in about 50% points.
3. Working passes at the wrong speed and during turns should be strictly avoided, as the momentary doses of liquid may differ significantly and even exceed the manufacturers' recommendations of pesticides.
4. There is an urgent need to develop a systematic training system designed to improve the awareness among operators about the causes of changes in parameters of work of the field sprayer during chemical plant protection treatments.

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