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THE PROGNOSTIC SIMULATION OF THE MOMENTARY DOSE OF LIQUID APPLIED BY THE FIELD SPRAYER WITH 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 with an automatic pressure control. The simulation used, registered at frequency of 1 Hz, data regarding speed, the direction of movement and the position coordinates of the sprayer during the process of plant protection on field. Based on the results, it was found that while ride parallel along the straight technological paths about half of the surface of the field is covered with a liquid in an amount different from the intended at least ± 5%; and, furthermore, that should be strictly avoided to twist during working passes, because the momentary liquid dose may even exceed many times the manufacturers' recommendations of pesticides and liquid fertilizers.
Key words*: field sprayer, plant protection products, liquid fertilizers, spray, momentary dose*

SYMULACJA PROGNOSTYCZNA CHWILOWEJ DAWKI CIECZY APLIKOWANEJ PRZEZ OPRYSKIWACZ POLOWY Z AUTOMATYCZNĄ REGULACJĄ CIŚNIENIA

Streszczenie

W artykule przedstawiono wyniki symulacji prognostycznej dotyczącej chwilowej dawki cieczy aplikowanej przez opryskiwacz polowy wyposażony w automatyczny układ regulacji ciśnienia. W symulacji wykorzystano zarejestrowane z częstotliwością 1 Hz dane dotyczące prędkości, kierunku ruchu oraz współrzędnych położenia opryskiwacza podczas procesu ochrony roślin na polu. Na podstawie uzyskanych rezultatów stwierdzono, że podczas przejazdów równoległych wzdłuż prostoliniowych ścieżek technologicznych około połowy powierzchni pola zostaje pokryte cieczą w ilości różniącej się od zamierzonej o co najmniej ±5%, a ponadto, że należy rygorystycznie unikać przejazdów roboczych podczas skrętów, gdyż chwilowe dawki cieczy mogą nawet wielokrotnie przekraczać zalecenia producentów środków ochrony roślin i nawozów płynnych.
Słowa kluczowe*: opryskiwacz polowy, środki ochrony roślin, nawozy płynne, oprysk, dawka chwilowa*

1. Introduction

Chemical plant protection products are very significant in increasing the efficiency and quality of agricultural production. Conducted in the European Union strategy for sustainable use of pesticides should lead to the elimination of the risks that are associated with their use [1]. In recent times in Poland, an increased use of pesticides has been recorded. The increase has also occurred in the acreage, on which the measures are carried out with using of these preparations. Entering various types of chemicals to agricultural crops deserve special attention because of their toxicity, the ability to accumulate, and durability in the environment [3]. The basic principle of the implementation of effective plant protection measures by spraying is precisely applying usable spray on treated objects in such a way that the plant protection product was possibly evenly deposited on the entire protected surface, individual parts of plants or properly applied to harmful organisms [4]. Modern plant protection places high demands inter alia for technology of protection products, with special emphasis on precise and environment friendly technique of spraying. In practice, for the spraying of field plants is using a variety of sprayers such as: tractor sprayer liftmounted and trailed, and self propelled sprayers. Use of machinery for the application of plant protection products is limited by the many legal regulations and international standards [6]. In Poland since 1999, a mandatory inspection of sprayers is conducted. The national system of inspection of sprayers is organized and controlled by the State Inspectorate of Plant Health and Seed [7]. Spray uniformity is especially important in the use of chemicals with a high concentration because otherwise it may cause local destruction of crops or ineffectiveness of treatment [8]. For this reason, treatment of chemical protection of plants and liquid fertilization performed by field sprayer should be carried out during rectilinear crossings. In general, chemical protective treatments are carried out using the technological paths. Paths should be established with great care, which allows to cut back the surface twice sprayed or without spraying. The best results in establishing technological paths are achieved when using automatic guidance systems [9]. In practice sprayers rectilinear tracking dominate, but due to the irregular shapes of fields and existing obstacles, the farmer often in every field is forced to spray during a turn. According to the opinion of many specialists the study to determine the effect of the position of the boom and movement of the generator for spray distribution and coverage of sprayed objects are advisable. Especially great advantage could bring mathematical descriptions of the volumetric distribution of liquid, depending on the parameters adopted in varying operating conditions sprayer. The mathematical description of the spraying process would allow the determination of the distribution of the liquid without conducting time-consuming and expensive laboratory and field tests[10].

2. The aim of the study

The purpose of this study was simulation which refers to the momentary dose of liquid applied by the field sprayer with an automatic pressure control. 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 plant protection on field.

3. Materials and methods

The field study was conducted in the West Pomeranian voivodeship in the county Choszczno, the municipality Drawno in locality Brzeziny (53° 08'29 .7" N 15° 40'52 .5" E). The experience was performed on 10.10.2013 during the spraying herbicide on winter rye grown 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 aggregated with the liftmounted field sprayer with a working width of 20 m was used. On the field beam 41 nozzles were disposed at distances of 0,5. Sprayer was fully technically efficient and had equipment for maintaining a constant dose of the liquid in the rectilinear tracking regardless of the speed and the amount of the included section. It was assumed that the only factor affecting the momentary dose of liquid per unit area of the field is a change of the direction of movement of the sprayer. Agricultural aggregate was moving in technological paths. During tracking the operator had the ability to control the sprayer working sections from the tractor cab. For monitoring of sprayer`s route recorder consisting of a microcontroller, a GPS, electronic compass, and specialized software was used. The measuring elements were located on the sprayer boom and coincide with the longitudinal axis of symmetry of the machine aggregate. Accuracy of the position measurement was 0,3 m, the speed of 0,1 $m \cdot s^{-1}$ and the direction of movement 0,1 degrees. Registration of data were made on the SD card with a frequency of 1 Hz. 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 traveled 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 the ranges of 95 - 105% of the adjustment dose. Other distribution compartments 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. Separately, presented the results for the parallel passes along the technological paths of the spray made on the outskirts of and for the entire field. For the calculations Excel 2010 spreadsheet was used, and to illustrate them Statistica, 2010.

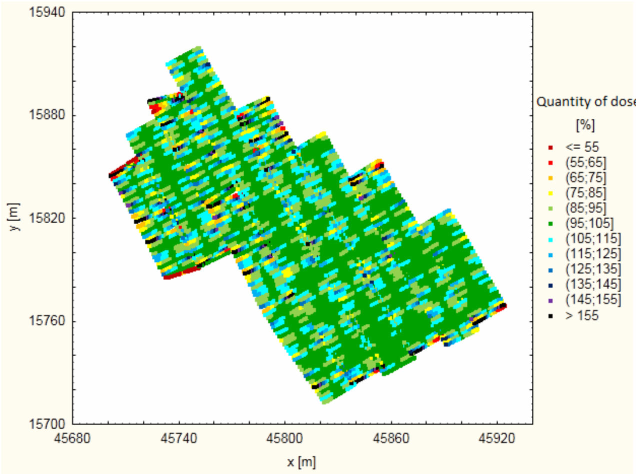
4. Results

The route of the sprayer through the field during spraying was determined on the basis of the done measurements (Fig. 1). Satellite photo taken during one of the previous agronomic seasons was used as a background to illustrate this route, thus route of crossing does not fully coincide with the layout of route showing in the photograph. Illustration does not include rides during turning back, as turning on the recorder of parameters of sprayer`s motion was followed simultaneously with the process of activating the spray by the operator. Due to the irregular shape of the field, some active crossings or their parts were carried out using the parts of the spray`s section. During performed tests we collected data on 867 consecutive measurement points, which corresponds to the time of work of the sprayer, expressed in seconds. Based on the illustration it can be concluded that some of the technological paths, generally contrary to the operator's intentions are not perfectly rectilinear. Furthermore, the distance between adjacent paths has too big scattering

Source: Own work based on Google Earth / Źródło: opracowanie własne na podstawie Google Earth

Fig. 1. The road passed by the sprayer while performing protection measures
Rys. 1. Trasa przejazdu opryskiwacza podczas wykonywania zabiegu ochrony chemicznej

Figure 2 presents the momentary dose of liquid during performing parallel crossings along the technological paths. Although technological paths were mostly almost rectilinear, it can be observed that numerous and significant differences in the amount of applied product. The operator started chemical protection from technological path shown in the figure in the lower part on the right side. After reaching the end of the technological path the operator performed a return and entered on the adjacent path. In an analogous manner he continued spraying when moving the vehicle along the next technological paths. The largest diversity of the momentary dose occurred when starting of spraying This results from the fact that the operator performed several tasks simultaneously, i.e. drove the aggregate, turned on the spray and observed the work of the sprayer. In the following crossings the operator`s attention was focused mainly on driving the aggregate. Although the crossing took place along the rectilinear technological paths, the operator was moving the steering wheel periodically to keep the right direction of passing and this can be a reason of changes in the momentary dose of liquid in multiple measuring points. May be assumed that the bumpiness of field`s surface had an impact on changing the direction of movement of the aggregate.

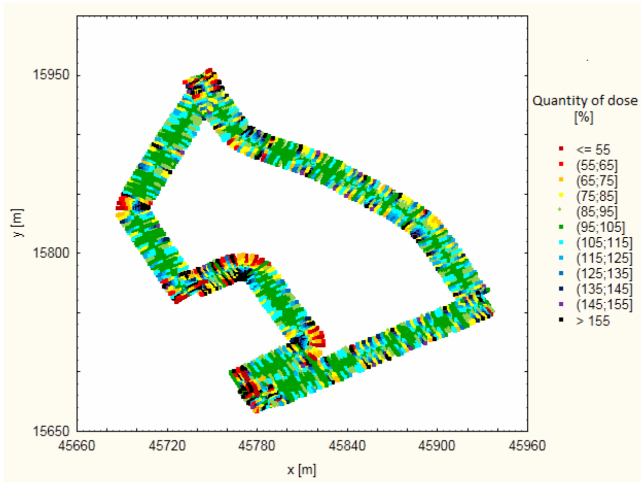


Source: Own tests / Źródło: Opracowanie własne

Fig. 2. Superficial distribution of the momentary dose of liquid applied during parallel crossings
Rys. 2. Rozkład powierzchniowy chwilowych dawek cieczy aplikowanej podczas przejazdów równoległych

The histogram of the temporary dose of spray during parallel crossings on technological paths are shown in fig. 3. A graph was prepared on the basis of about 20 000 results of calculation. More than half of the field area (54,4%) was covered with the right amount of plant protection products. In the ranges of 85-115% were over 85% of the estimated doses. In the dose range ≤ 55% reported 94 cases, which represents 0,5% of all results, and in case of the range> 155% the number of the momentary doses was 283, i.e. 1.4%.

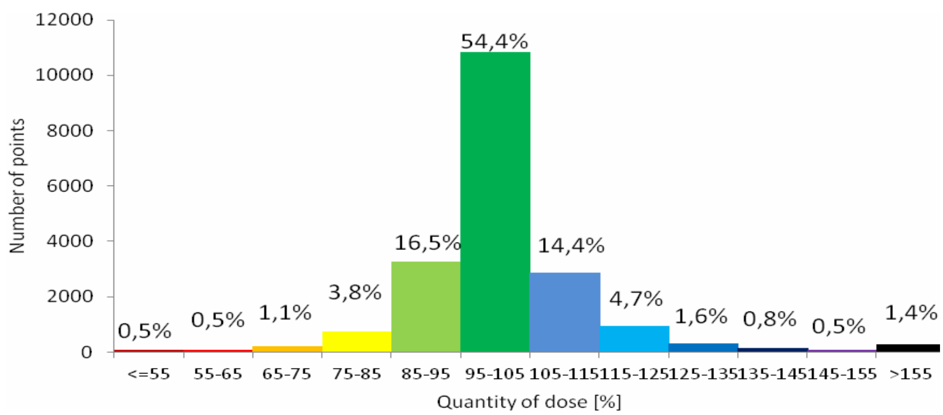
Figure 4 shows the surface distribution of momentary dose of liquid applied on the outskirts of the field. Spraying was made during the four working passes separated by returns. Technological paths on a significant length were rectilinear so momentary dosages of the liquid had partially similar distribution as during the previously described parallel crossings. Much more disadvantageous results were observed during crossing of the farm aggregate on curves. Because of the large working width of the sprayer significant variation of speed of particular sprayers against the surface of the field had occurred, what with constant expenditure of liquid caused large spread momentary doses. The largest from the calculated momentary doses reached a level 1230% of the regulatory dose. At the same time on the opposite end of the boom momentary dose was a little higher than 50% of the regulatory dose.



Source: Own tests / Źródło: Opracowanie własne

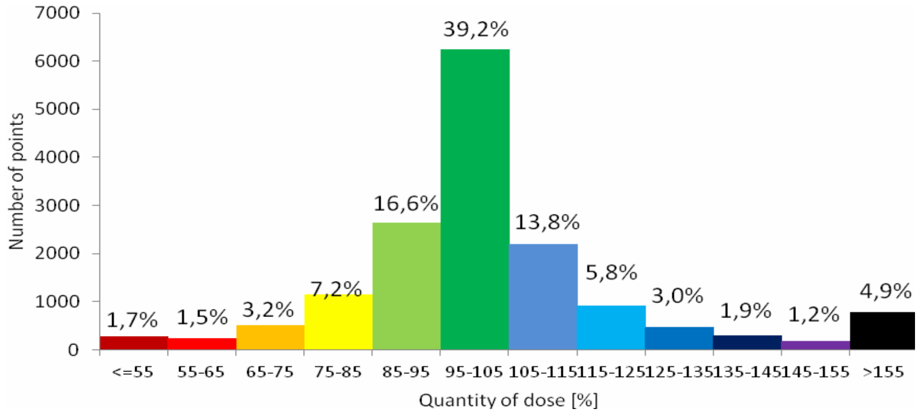
Fig. 4. Surface distribution of momentary dose of liquid applied on the outskirts of the field
Rys. 4. Rozkład powierzchniowy chwilowych dawek cieczy aplikowanej na obrzeżach pola

Figure 5 contains a histogram of momentary dose of spray during the crossings through the technological paths located on the outskirts of the field. This chart is based upon the results regarding nearly 16 000 of the estimated momentary doses.



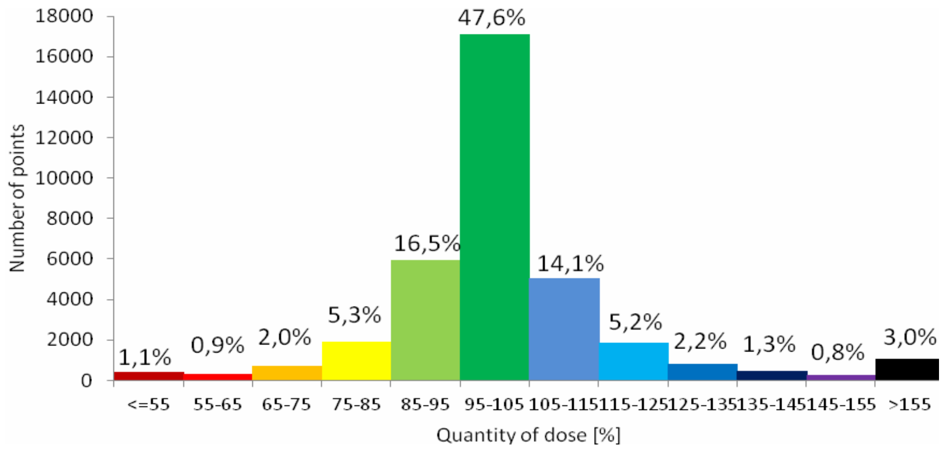
Source: Own tests / Źródło: Opracowanie własne

Fig. 3. The histogram of the momentary dose of spray during parallel crossings
Rys. 3. Histogram chwilowej dawki oprysku podczas przejazdów równoległych



Source: Own tests / Źródło: Opracowanie własne

Fig. 5. The histogram of the dose of spray during crossing on the outskirts of the field in the technological paths
Rys. 5. Histogram dawki oprysku podczas przejazdu po obrzeżach pola w ścieżkach technologicznych



Source: Own tests / Źródło: Opracowanie własne

Fig. 6. The histogram of the momentary dose of spray on the entire acreage
Rys. 6. Histogram chwilowej dawki oprysku na całym areale

The largest number of doses of momentary (6250) belonged to the range of 95-105%, which represents 39,2% of the results relating to outskirts of the field, and, in the case of range concerning the dose of ≤ 55% observation 278 (1,7%) had occurred. There was a relatively large number of results, i.e. 781, relating to doses greater than 155%, which is 4,9% of the total estimated doses.

The results regarding the distribution of the momentary dose of spray for the entire field are shown in Figure 6. The optimal, conforming with the assumptions, dose of spray covered less than half the surface of the field, i.e. 47,6%. Too high momentary dose occurred in 26,6% of the measurement points. Too low dose has been found in a bit smaller amount of cases i.e. 25,8% of points. The momentary dose within the range 85-115% of the regulatory dose had been covered about ¾ of the total area of the field. A relatively large number (3%) of measuring points was characterized by momentary dose greater than 155% of the regulatory dose. In one of the measurement point has been found the dose more than 12-fold excess the regulatory dose. The dose less than 55% was recorded for 1,1% of all cases.

In conclusion it should be emphasized, that presented results relates to the chemical protection performed by using modern equipment, significant independence of the momentary dose from minor changes in speed of movement of the aggregate. In the national agriculture such sprayers are few, and in the case of less modern sprayers can be assumed that variation of the momentary dose is significantly greater than in the presented simulation, as an additional disrupting factor may be inappropriate, or unequal operating speed of the aggregate.

5. Conclusions

Based on conducted studies following conclusions were formulated:

1. For the determination of momentary dose of liquid the applied by nozzles prognostic simulation can be used, which use data concerning the crossings' parameters of field sprayer.
2. During parallel crossings along rectilinear technological paths about half of surface of the field is covered with liquid in an amount which differs from the intended at least ± 5%.
3. The working passes during twists should be strictly avoided, because momentary dose of the liquid may even exceed many times the producers recommendation of plant protection products and liquid fertilizers.
4. There is an urgent need for research and implementation works in order to improve the operational performance of field sprayers.

6. References

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