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Evaluation of resistance to spray drift of selected sprayer nozzles in the aspect of non-uniformity in transverse distribution of liquid

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Summary. The article presents an evaluation of resistance to spray drift of selected flat-jet sprayer nozzles, characterized by the effect of wind speed, on non-uniformity in transverse distribution of sprays. Measurements were made on an automated laboratory station equipped with a fan and sensors for measuring wind speed and wind direction [4, 5, 8]. The study adopted the following criteria for evaluation of the tested sprayer nozzles: CV index of non-uniformity in transverse distribution of liquid (with a maximum permissible value of 10%) and the number of measuring cylinders in which the liquid volume does not exceed ±10% of their average value. The results of laboratory tests and the above-mentioned criteria were used to assess which sprayer nozzles had the greatest resistance to spray drift within the range of the adopted variations in wind speed.

Key words: spray drift, wind speed, sprayer nozzle, crop spraying; laboratory station, non-uniformity in transverse distribution of liquid, CV index.

INTRODUCTION

In order to ensure high quality of crops, researchers have been trying to increase the quality and effectiveness of the crop spraying process while reducing the dose of chemical preparations that have an adverse effect on the environment. There is a number of studies that aim to determine which external factors affect the effectiveness and quality of the crop spraying process. One of the most important indicators that characterize the quality of this process is the non-uniformity in transverse distribution of liquid characterized by the CV index. It is also important to identify the relationship between the CV index that characterizes the process quality and the factors that influence its value. The analysis of literature [1, 2, 17] and previous studies indicate that the value of the CV index is influenced by a large number of external factors accompanying the crop spraying process, including air (wind) movement. For this reason, a large degree of importance is attached to the structure of sprayers and sprayer nozzles, as well as their proper selection during the process conducted under adverse external influences. Spray drift, as an unintended effect of the action of air currents, has a very negative effect on the quality and effectiveness of the crop spraying process and has negative implications in both ecological and economic terms. According to *ISO 22866*, drift is the quantity of plant protection product (p.p.p.) that is carried out of the sprayed (treated) area by the action of air currents during the application process [13]. For this reason, all possible measures and methods should be applied to minimize spray drift. The intensity and range of drift depends on atmospheric conditions during the spraying process.

There are a lot of negative consequences of spray drift that affect the effectiveness of spraying. What follows are a few examples of the most significant negative consequences:

- loss of p.p.p. in economic terms,
- reduced plant protection efficacy due to reduced application of the product on sprayed objects,
- residues of unauthorized p.p.p. in adjacent crops that were not the subject of the spraying process,
- pollution of the environment, including in particular surface water,
- damage to sensitive plants and organisms that were not the target of the spraying process,
- immediate threats to human and animal health, [2, 14].

Drift reduction techniques (DRT) play a key role in reducing drift outside the sprayed area. One of the most important techniques is the use of sprayer nozzles. Fine droplets (with a diameter of less than 100 μm), which are contained in drop spectrum produced by the most commonly used pressure sprayers, are particularly susceptible to drift.

Although the use of sprayer nozzles with increased flow rate and liquid pressure reduction are the simplest and least expensive techniques used to increase the size of droplets produced by traditional hydraulic sprayer nozzles, the effects of such techniques are not sufficient. Consequently, agricultural practice introduced a drift reducing technique that uses sprayer nozzles which were specially designed to produce larger droplets. A major advantage of reducing drift with the use of such sprayer nozzles is relatively moderate cost and the possibility of applying this technique in almost every sprayer nozzle without the need to interfere with its structure. Numerous scientific studies have shown that drift reducing sprayer nozzles are almost as effective as traditional ones. However, a few studies have shown that the use of such sprayer nozzles is less effective in terms of protection. There is therefore a need for studies that aim to improve the knowledge of the adverse effects of external factors, such as wind, on the quality and effectiveness of crop spraying process. This paper attempts to evaluate the resistance to spray drift of selected flat-jet sprayer nozzles.

AIM OF THE STUDY

The aim of this study is to investigate and evaluate the effect of wind speed on non-uniformity in transverse distribution of sprays characterized by the value of the CV index, when drift reducing sprayer nozzles are mounted on the sprayer boom.

MATERIALS AND METHODS

The study was conducted in the laboratory of the Institute of Mechanical Engineering at the Warsaw University of Technology Branch in Plock. Measurements were made on an automated laboratory station equipped with a slot table with a slot width of 25 mm [5, 6, 7]. View of the laboratory station is shown in Figure 1.

The study included one copy of each 6 sprayer nozzle types (of four different manufacturers) used in field sprayers, the indications of which are given in Table 1.

Laboratory tests using the aforementioned station were carried out in accordance with the requirements and recommendations of ISO standards [9, 10, 11, 12], in particular:

- the working medium was pure water free from suspended solids and its temperature did not exceed the range of 10°C to 25°C,
- the accuracy of the liquid volume reading in a single measuring vessel was 1 ml, which resulted from the measurement method (digital image analysis),
- the ambient temperature during tests ranged from 15°C to 20°C,
- the accuracy of the working pressure reading was ±0.1 bar,
- individual measurements were taken in less than 30 seconds,
- the accuracy of the sprayer nozzle height reading above the measuring table was ±0.01m,
- the accuracy of the sprayer nozzle setting angle reading in relation to ±1° level.

Measurements for each of the selected sprayer nozzles were made in the range of variations in wind speed within the range of 0 to 6 m/s (variation every 1 m/s), with a fixed angle of wind speed vector in relation to the sprayer nozzle direction of 90˚. During measurements, a fixed height of the sprayer boom above the measuring table surface was maintained at 0.5 m and the working pressure was maintained at 3 bars. The measuring time was 120 s.

Fig. 1. View of the laboratory station used in the study.

The laboratory station was equipped with an automatic control system that allowed to eliminate the working pressure fluctuations and to obtain the predetermined spray rate at the time of measurements. The system consisted of a precision flowmeter, pressure sensor, wind speed sensor and valves: stepless valve, pressure control valve and shutoff valve that were connected to a measuring card and a computer. At the time of measurements, the values of the aforementioned operating parameters and the volume of liquid accumulated in the individual measuring cylinders of the slot table were recorded in computer memory.

The measure used to evaluate the resistance to drift of the tested sprayer nozzles within the adopted range of wind speed variations was the value of non-uniformity in transverse distribution of liquid (the CV index) which was determined on the basis of the recorded liquid volumes in individual measuring cylinders.

The original computer program, which the laboratory station is equipped with, allows to set the value of the CV index for both the individual sprayer nozzles and the so-called “virtual” sprayer boom composed of the appropriate number of tested sprayer nozzles. Simulation of the “virtual” boom is based on the volume of liquid collected from slots with a width of 25 mm and application of streams from the coverage area. These volumes were subsequently aggregated to a slot with a width of 100 mm (according to ISO requirements). The volumes of liquid coming from the adjacent sprayer nozzles on the “virtual” boom were aggregated in such a way that the liquid streams overlapped each other and the sprayer nozzle axes were spaced at 0.5 m, giving identical liquid distribution as for the actual sprayer boom [15]. Based on the obtained results, it was possible to calculate values of the CV index for the sprayer boom, assuming a maximum value of 10% as the evaluation criterion, and the number of cylinders where the liquid volume did not exceed ± 10% of their average value.

RESULTS AND DISCUSSION

Table 1 summarizes the values of the CV index (average value of three measurement repetitions) for the tested sprayer nozzle types. The results were summarized for the adopted wind speed range of 0÷6 m/s. The CV index values obtained for the “virtual” sprayer boom were also presented for each sprayer nozzle type. The results were arranged by order of measurements. The determined values of the CV index for individual sprayer nozzles play a comparative role, whereas those determined for the sprayer boom become a direct evaluation of the spray quality for the range of the tested wind speed variations.

Table 1. Summary of measurement results for the tested sprayer nozzles and sprayer boom at a speed within the range of 0÷6 m/s and height of 0.5 m above the measuring table:

- both the evaluation criteria were met,
- one evaluation criterion was met,
- neither of the evaluation criteria was met.

sprayer nozzle	Measurement No.	Wind speed, [m/s]	CV index for a single sprayer nozzle, [%]	CV index for sprayer boom consisting of the same sprayer nozzles, [%]	Number of cylinders with a deviation greater than ± 10 %	Average value [ml]
AZ-MM 110/03	1	0	54,8	2,3	0	387
	2	1	60,8	7,4	0	417
	3	2	55,6	7,3	5	399
	4	3	57,6	4,7	0	393
	5	4	59,1	4,8	0	382
	6	5	64,6	3,9	0	359
	7	6	76	6,3	1	353
AirMix 110-03	1	0	57,1	1,3	0	457
	2	1	62,7	1,5	0	459
	3	2	60,8	3,1	0	451
	4	3	64	4,1	0	437
	5	4	65,7	5,1	0	425
	6	5	71,5	7,3	5	438
	7	6	77,8	10,2	9	430
EŻK 110-03	1	0	61,2	13,8	14	405
	2	1	60,9	15,9	19	429
	3	2	60,3	14,2	14	437
	4	3	65,7	13,4	14	419
	5	4	66,2	13,1	19	419
	6	5	69,2	12,8	14	398
	7	6	77,8	14,2	19	394
AP 6MS 03C2	1	0	44,4	20,1	24	361
	2	1	46,8	17,8	19	432
	3	2	49,4	17,6	14	420
	4	3	51,9	16,1	19	406
	5	4	51,2	15,2	19	400
	6	5	59,4	13,7	15	404
	7	6	60	13	15	399
EŻ 110-03	1	0	38,4	16,5	24	411
	2	1	43,4	16,6	14	438
	3	2	42,6	15,8	14	428
	4	3	46,7	14,4	14	420
	5	4	51,3	13,2	15	420
	6	5	53,5	12,3	15	414
	7	6	56,2	10,3	10	408
XL 03	1	0	54,7	5,2	0	461
	2	1	56,8	3,3	0	458
	3	2	63,1	3,7	0	457
	4	3	65,8	6,1	0	452
	5	4	71,1	7,7	5	458
	6	5	74,5	11,6	10	439
	7	6	80,9	13,8	10	439

The analysis of the results presented in table 1 for the AZ-MM 110/03 sprayer nozzle indicates that the value of the CV index for a single sprayer nozzle is not directly proportional to the value of the CV index for the sprayer boom (within the range of the tested wind speed variations). It was also observed that when the CV index for a single sprayer nozzle has a small value which increases as the wind speed increases, it does not necessarily have to exhibit an upward trend for the sprayer boom consisting of the same sprayer nozzles.

It was also observed that the CV index for the sprayer boom using the AZ-MM 110/03 sprayer nozzle does not exceed 10%, while the same measurements evaluated on the basis of the second criterion do not meet it in two cases, at speeds of 2 and 6 m/s they are characterized by any number greater than zero of cylinders (5 and 1, respectively) with a volume deviation greater than ± 10% of the average value. It was also observed that evaluation of the same measurements may differ in terms of the adopted criteria. Figures 2 and 3 present exemplary measurement results illustrating the described situation (the AZ-MM 110/03 sprayer nozzle) at two wind speeds.

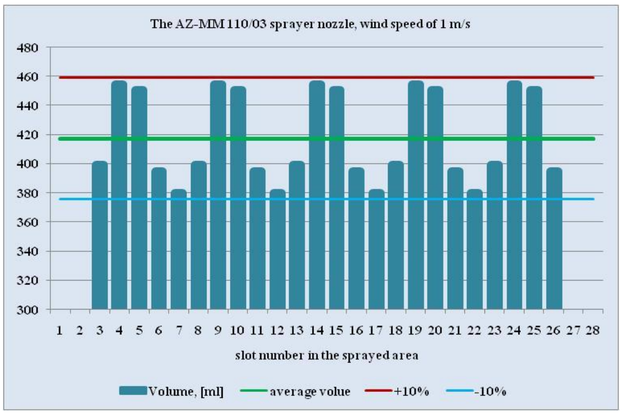

Fig. 2. Chart showing the liquid volume in the sprayed area using the AZ-MM 110/03 sprayer nozzle at the wind speed of 1 m/s (value of the CV index equal to 7.4%)

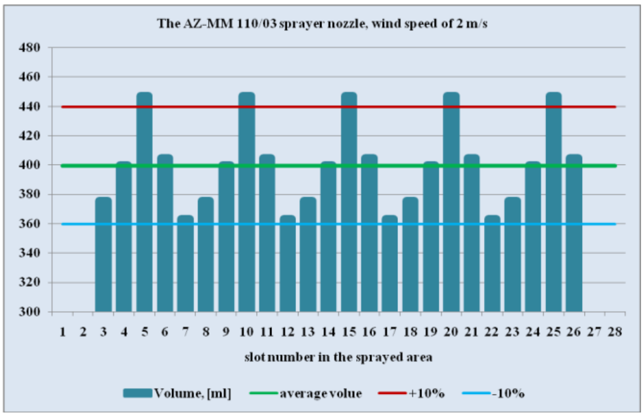

Fig. 3. Chart showing the liquid volume in the sprayed area using the AZ-MM 110/03 sprayer nozzle at the wind speed of 2 m/s (value of the CV index equal to 7.3%)

It was noted that the value of the CV index is 7.4% at a wind speed of 1 m/s, and the number of cylinders with a deviation of more than ±10% is 0. On the other hand, the value of the CV index is 7.3% at a wind speed of 2 m/s, and the number of cylinders with exceeded deviation is 5.

The analysis of the results for the AirMix 110-03 sprayer nozzle indicates that the value of the CV index at a wind speed of 0÷5 m/s does not exceed the permissible value of 10%. The CV index increased for a single sprayer nozzle and for the sprayer boom consisting of the same sprayer nozzles. It can be stated that the AirMix 110-03 sprayer nozzle has very good resistance to drift at a wind speed within the range of 0÷4 m/s, which serves as proof of compliance with both of the adopted evaluation criteria. This sprayer nozzle has slightly worse resistance at a wind speed of 5 m/s, but only because of the second evaluation criterion. Both criteria were not met at a wind speed of 6 m/s.

The analysis of the results for the EŻK 110-03, AP 6MS 03C2 and EŻ 110-03 sprayer nozzles indicates that the CV index for the sprayer boom in all of the measurements was not less than 10%. A significant number of cylinders with a deviation greater than ±10% of the average value was also obtained.

Based on the results obtained for the AP 6MS 03C2 and EŻ 110-03 sprayer nozzles, the authors of this paper observed an increase in the CV index value for a single sprayer nozzle along with an increase in wind speed, and a decrease in the CV index value for the sprayer boom consisting of the same sprayer nozzles. Lower values of the CV index than those obtained for the AP 6MS 03C2 sprayer nozzle were observed in the case of a single EŻ 110-03 sprayer nozzle and the entire sprayer boom equipped with this type of sprayer nozzles. The values of the CV index for a single sprayer nozzle are surprisingly low. The lowest value is 38.4% at zero wind speed, and the highest value is 56.2% at wind speed of 6 m/s. For the boom, the CV index value at zero wind speed is 16.5%, and its value decreases with increasing wind speed. The value of this index at a wind speed of 6 m/s is 10.3%. Although the AP 6MS 03C2 and EŻ 110-03 sprayer nozzles show negative results in terms of the adopted evaluation criteria, the obtained results are interesting. The obtained characteristics are unusual in comparison to other tested sprayer nozzles.

The analysis of the results for the XL 03 sprayer nozzle indicates significant CV index values for a single sprayer nozzle that increased at a speed within the range of 0÷6 m/s, and it reached 80.9% at a wind speed of 6 m/s. A positive result (the CV index value was less than 10%) was obtained for the boom equipped with this type of sprayer nozzles at a speed within the range of 0÷4 m/s. The CV index value at wind speeds of 5 and 6 m/s were 11.6% and 13.8%, respectively, and it did not met the first criterion. The sprayer nozzle met evaluation criteria at a speed within the range of 0÷3 m/s. Therefore, it can be stated that the XL 03 sprayer nozzle is characterized by fairly good resistance to spray drift. When the wind speed rises to 4 m/s, the value of the CV index reaches 7.7%. However, the number of cylinders with exceeded deviation is 5 and therefore it does not meet the second criterion. The CV index values at wind speeds of 5 and 6 m/s are 11.6% and 13.8%, respectively, and the number of cylinders with exceeded deviation in both measurements was 10. Therefore, in this case the second criterion was not met.

Evaluation of resistance to spray drift was done by dividing the tested sprayer nozzles into two groups, respectively:

I – (AZ-MM 110/03, AirMix 110-03, XL 03),

II – (EŻK 110-03, AP 6MS 03C2, EŻ 110-03).

Sprayer nozzles from the first group are distinguished from all other tested sprayer nozzles. Both evaluation criteria had good and very good spray drift resistance within the tested speed range.

None of the above mentioned sprayer nozzles from the second group achieved the CV index values below 10%. These sprayer nozzles have very poor resistance to spray drift (in comparison to sprayer nozzles from the first group) within the entire speed range of 1÷6 m/s. The characteristics of two sprayer nozzles from the second group (AP 6MS 03C2 and EŻ 110-03) should be considered surprising because, despite the significant values of the CV index for the boom, these values decreased with increasing wind speed.

CONCLUSIONS

Based on the analysis of the results it was concluded that:

- an important factor for the evaluation of resistance to spray drift is not only the value of the CV index for the sprayer boom consisting of the tested sprayer nozzles, but also the number of cylinders in which the liquid volume exceeds ±10% of their average value. A negative consequence of the crop spraying process may be the spraying strands with increased or reduced dose of plant protection product,
- high value of the CV index for a single sprayer nozzle does not imply that the value of the CV index for the sprayer boom will exceed the limit value,
- the AZ-MM 110/03 sprayer nozzle, as the only one of the tested sprayer nozzles, obtained a CV index of less than 10% within the entire range of wind speed variations (0÷6 m/s),
- the AirMix 110-03 sprayer nozzle has the lowest values of the CV index for the sprayer boom within the speed range of 0÷4 m/s; for this range the second evaluation criterion was also met,
- the XL 03 sprayer nozzle achieved the CV index values of less than 10% at speeds within the range of 0÷4 m/s. The second criterion was not met for the speed of 4÷6 m/s,
- the CV index value for the sprayer boom using the EŻ 110-03 sprayer nozzle decreased with increasing wind speed.

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OCENA ODPORNOŚCI NA ZNOSZENIE CIECZY WYBRANYCH ROZPYLACZY W ASPEKCIE NIERÓWNOMIERNOŚCI POPRZECZNEGO ROZKŁADU CIECZY

Streszczenie. W artykule przedstawiono ocenę odporności na znoszenie cieczy wybranych płaskostrumieniowych rozpylaczy, charakteryzowaną wpływem prędkości wiatru na nierównomierność rozkładu poprzecznego rozpylonej cieczy. Wykonano pomiary na zautomatyzowanym stanowisku laboratoryjnym, wyposażonym w wentylator i czujniki pomiaru prędkości i kierunku wiatru [4, 5, 8]. Jako kryteria oceny wyników przeprowadzonych badań jakości pracy badanych rozpylaczy, przyjęto: wartość wskaźnika CV nierównomierności rozkładu poprzecznego cieczy (o maksymalnej wartości dopuszczalnej wynoszącej 10%), a także liczbę cylindrów pomiarowych, w których zgromadzona objętość cieczy nie przekracza ±10% ich wartości średniej. Na podstawie uzyskanych wyników badań laboratoryjnych oraz w.w. kryteriów oceniono, które rozpylacze cechują się największą odpornością na znoszenie w zakresie przyjętych zmian prędkości wiatru.

Słowa kluczowe: znoszenie cieczy, prędkość wiatru, rozpylacz, opryskiwanie; stanowisko laboratoryjne, nierównomierność rozkładu poprzecznego cieczy, wskaźnik CV.