Influence of wind direction and speed on the transverse fall of the sprayed liquid for selected flat-stream nozzles

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Abstract. The paper presents the assessment of the influence of wind direction and speed on the transverse fall of sprayed liquid for selected types of flat-stream nozzles. The measurements were carried out in laboratory conditions on an automated station equipped with a radial fan, speed and wind direction sensors, and a computer system for automatic acquisition and processing of measurement results. As criteria for the evaluation of the results of the conducted research on the quality of work of the tested nozzles, the values of the transverse non-uniformity index of CV liquid fall were assumed (with a maximum admissible value of 10%). The obtained results of laboratory tests were presented in the form of tables, and on their basis the dependencies of the CV index value on wind direction and wind speed were determined. On the basis of the obtained dependences, the assessment of individual nozzles was made due to the accepted criterion in the scope of the studied changes in wind speed and direction.

Key words: spraying of plants, quality and effectiveness of the treatment, wind direction and speed, flat-stream nozzle, liquid drift, laboratory stand, transverse liquid fall CV unevenness indicator.

INTRODUCTION

The chemical method among other methods of plant protection (agrotechnical, physical, mechanical, biological) against pests, diseases and weeds is still one of the most effective ones and is expected to continue to play an important role in the future. Many authors emphasize the fact that obtaining high yields of good quality is possible only through the use of chemical plant protection products, but it requires appropriate knowledge and responsibility, and above all properly selected and technically efficient equipment, [2, 15÷18]. Otherwise, chemical protection of plants carries serious risks for producers - farmers, consumers of agricultural products, but also for the natural environment [1, 2, 4]. Therefore, it is so important to know the influence of various factors (atmospheric, technical, etc.) on the indicators characterizing the quality and effectiveness of spray treatments with the use of chemical plant protection chemicals. One of the most commonly used for the quality assessment of spraying is the transverse unevenness index of the CV liquid fall. The other ones are: the degree of coverage and the degree of application of the spray liquid to the sprayed objects [18].

The results of many authors' research indicate unambiguously that one of the most important atmospheric factors adversely affecting the quality and effectiveness of spraying operations is the wind, which causes the drift of the useful liquid out of the target objects [2, 4]. According to ISO 22866, drift is the amount of plant protection product that is moved out of the target area by the action of air movement during the spraying operation [11]. In the literature, there are many examples of research on this phenomenon, and in practice a whole range of technical solutions are applied that limit drift and at the same time support the process of applying biologically active substances to sprayed objects [18]. It is possible to mention here the use of special anti-drift, ejector, double-stream sprayers or equipment of spraying beams in auxiliary air stream systems, [18]. Despite the fact that so far many research works have been devoted to the drift of liquid usable issues, not all dependencies related to the quality and effectiveness of spraying for many existing spray nozzles on the market have been clarified [3, 16, 18]. This applies in particular to the influence of wind speed and direction on the quality of the spraying treatment characterized by the transverse unevenness of the CV liquid fall. For this reason, the paper attempts to assess the effect of wind direction and speed on the values of this index for selected flat-stream nozzles.

PURPOSE OF THE PAPER

The purpose of the paper is to assess the influence of wind direction and speed on one of the basic characteristics of the spray quality assessment, which is the index of transverse non-uniformity of the liquid spray fall for selected flat-stream nozzles.

MATERIALS AND RESEARCH METHODS

The research was carried out in the laboratory of the Institute of Mechanical Engineering of the Warsaw University of Technology, Branch in Płock. The measurements were made on an automated laboratory stand equipped with a grooved table with a groove width of 25 mm [5÷11]. The basic element of the stand is a radial fan with high stability of the speed of the air stream (wind) produced, which is regulated by changing the rotational speed of the drive motor. The stand has been equipped with a modern measuring and control system, which includes a computer, a measurement and control card, measuring transducers and executive elements. During measurements, the basic parameters of the stand's operation are recorded (liquid pressure, nozzle's height, liquid flow rate, wind speed, relative humidity, liquid and ambient temperature, etc.), as well as liquid volumes accumulated in individual measuring vessels.

The view of the laboratory stand was shown on figure 1.

Fig. 1. View of the laboratory stand used in the research

The subject of laboratory tests were randomly selected samples of flat-stream nozzles, commonly used in field sprayers. The designations and types of test nozzles are as follows:

- AirMix 110-03 – ejector nozzle produced by the German company Agrotop,
- AZ-MM 110-03 – anti-drift nozzle produced by the Polish company MMAT,
- RS-MM 110-03 – standard nozzle produced by the Polish company MMAT.

Laboratory tests using the aforementioned stand were carried out in accordance with the requirements and recommendations of the standards ISO [7÷11], and especially:

- the working medium was pure water free from solid suspensions, and its temperature did not exceed the range from 10°C to 25°C,
- the accuracy of reading the liquid volume in a single measuring vessel was ±1 ml, which results from the way of measurement (digital image analysis),
- the ambient temperature during the tests was from 15°C to 20°C,
- the accuracy of the working pressure reading was ±0,1 bar,
- the time of performing a single measurement was longer than 30 seconds,
- the accuracy of reading the nozzle height above the measuring table was ±0,01m,
- accuracy of readout of the nozzle angle relative to the horizontal ±1°.

Measurements for each of the selected nozzles were made for four directions of wind action (angle between the speed vector and the direction of the sprayer's movement), i.e.: 90 °, 60 °, 30 ° and 0 °. A graphical interpretation of the wind direction is shown in Figure 2. The range of wind speed changes ranged from 0 to 3 m/s (change every 0.5 m/s) for each of the four wind directions. During the measurements, a constant height value of the spray beam on the surface of the measuring table of 0.5 m and a working pressure of 3 bar was maintained. The measurements were repeated three times, and the time of each measurement was 120 s.

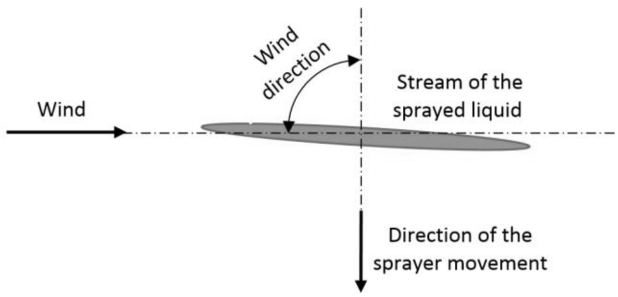

Fig. 2. Graphic interpretation of the wind direction influence

As a criterion for the assessment of the tested nozzles in the scope of changes of wind direction and speed, the values of transverse non-uniformity index of CV liquid fall were determined, based on the recorded liquid volumes from individual measuring cylinders.

The author's computer program, in which the laboratory stand is equipped, makes it possible to determine the value of the CV index for both individual nozzles and the so-called "virtual" spraying beam made up of an appropriate number of tested nozzles. Simulation of the "virtual" beam consists in taking into account the volume of liquid collected from grooves with a width of 25 mm and collecting streams from the area of their full coverage, and then aggregating these volumes to a groove width of 100 mm (in accordance with the requirements of ISO standards). The volume of liquid coming from neighboring nozzles on the "virtual" beam is aggregated in such a way that the liquid streams overlap, and the nozzle axes are spaced every 0.5 m, which gives the same distribution of liquid as for the actual beam of field sprayer. On the basis of the obtained results, the values of the CV index for the spray beam were calculated, taking as the criterion for the evaluation of the obtained results its limit value of max. 10%.

RESEARCH RESULTS AND DISCUSSION

Table 1 shows the CV index values (average value from three measurement repetitions) for individual nozzles of the tested types . The results were compared for the range of changes in the wind direction angle of 0 ÷ 90 ° adopted in the research and its speed in the range 0÷3 m/s. Figures 3 and 4 present examples of the dependencies of CV index value on the wind direction and its speed for a single AirMix 110-03 nozzle. CV index values determined for individual nozzles are used for comparative assessment of individual pieces, whereas those determined for the spray beam become a direct assessment of spraying quality for the studied range of changes in wind direction and wind speed.

Table 1. Comparison of the CV index values for single nozzles of tested types in the range of wind direction changes 0 ÷ 90 ° and its speed 0÷3 m/s

Nozzle	Wind speed, [m/s]	Wind direction			
		0°	30°	60°	90°
AirMix 110-03	0	56,9	56,9	56,9	56,9
	0,5	57	57,6	59,2	58,1
	1	57,3	58,1	61,9	60,8
	1,5	57,5	58,8	63,3	62,8
	2	58,2	59,7	64,3	63,6
	2,5	59,5	60,8	64,9	64
	3	61,7	62,8	65,6	64,2
AZ-MM 110-03	0	54,8	54,8	54,8	54,8
	0,5	55	55,3	57,9	55,4
	1	55,5	55,7	59,6	56,2
	1,5	56	56,2	60,2	57,2
	2	56,6	57,3	61	58,4
	2,5	57,6	58,1	61,4	59,3
	3	58,2	59,8	62,3	60,9
RS-MM 110-03	0	55,2	55,2	55,2	55,2
	0,5	56,1	55,8	58,4	60,8
	1	56,9	57,6	62,1	66,1
	1,5	57,6	58,8	64,2	68,8
	2	58,3	59,4	67,5	74,9
	2,5	59,1	64,4	73,3	77,3
	3	60,4	69,8	78,2	82,5

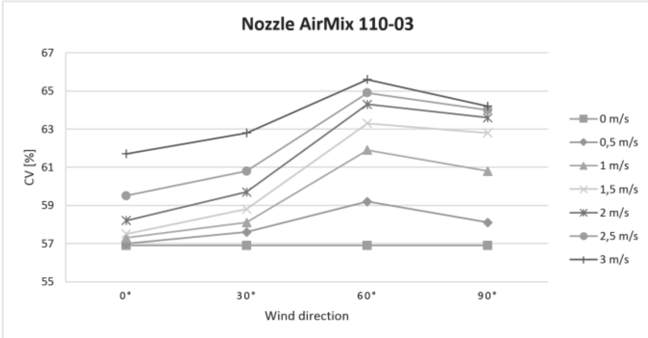

Fig. 3. Dependence of CV index value on wind direction for a single AirMix 110-03 nozzle

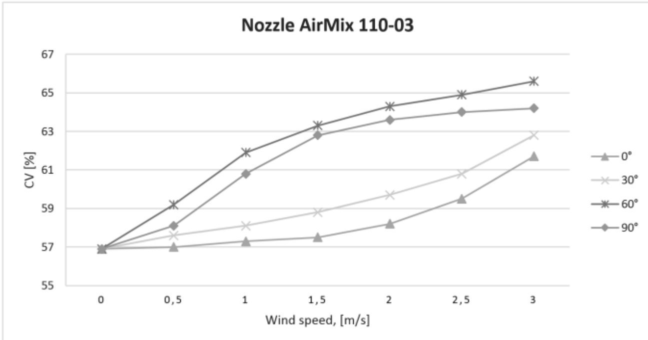

Fig. 4. Dependence of CV index value on wind speed for a single AirMix 110-03 nozzle

The analysis of the results presented in Table 1 indicates that the influence of wind direction and speed on the CV index values determined for individual nozzles is similar for all three types tested. An increase in the angle of the wind direction or its speed causes an increase in the value of the CV index. The exception is the angle of 90 ° for the AirMix 110-03 and AZ-MM 110-03 nozzles, for which a decrease in the CV index value is observed over the whole range of the tested speeds in comparison with the analog CV values for the direction of 60°. It is assumed that this may be due to the fact that both the AirMix 110-03 and AZ-MM 110-03 nozzle belong to the group of nozzles with increased drift resistance. For the standard sprayer RS-MM 110-03, the described situation does not occur and an increase in the wind direction causes a proportional increase in the CV index in the whole range of wind speed changes. For this nozzle, much higher values of the CV index for the angles of 60° and 90° are also observed. It was also observed that the intensity of the wind speed increases as the angle of direction increases. For angles of 0 ° and 30 ° the influence of wind speed is much lower than for angles of 60 ° and 90 °.

Below in table 2 (in the same way as for individual nozzles, CV values were compared, obtained for a "virtual" sprayer beam equipped with the tested type of nozzles. Figures 5 and 6 present examples of dependences of the CV ratio on the wind direction and its speed for a "virtual" spray beam equipped with AirMix 110-03 nozzles.

Table 2. Comparison of the CV index value for the "virtual" spray beam equipped with the tested nozzles types in the range of wind direction changes 0 ÷ 90 ° and its speed 0÷3 m/s

Nozzle	Wind speed, [m/s]	Wind direction			
		0°	30°	60°	90°
AirMix 110-03	0,0	1,3	1,3	1,3	1,3
	0,5	1,3	1,4	1,4	1,5
	1,0	1,4	1,6	1,7	1,8
	1,5	1,4	1,8	2,2	2,4
	2,0	1,5	2,1	2,8	3,1
	2,5	1,6	2,4	3,4	3,7
	3,0	1,7	2,8	4,1	4,4
AZ-MM 110-03	0,0	2,5	2,5	2,5	2,5
	0,5	2,6	2,8	3,7	4,2
	1,0	2,7	3,1	4,7	6,1
	1,5	2,8	3,4	5,6	6,5
	2,0	2,9	3,7	6,3	7,5
	2,5	3,1	4,2	6,9	8,1
	3,0	3,2	4,9	7,8	8,9
RS-MM 110-03	0,0	8,2	8,2	8,2	8,2
	0,5	8,4	8,5	8,9	9,1
	1,0	8,7	8,9	9,6	9,8
	1,5	9	9,2	10,3	10,9
	2,0	9,2	10,1	11,5	12,5
	2,5	9,3	10,9	13,3	15
	3,0	9,4	11,7	15,9	17,9

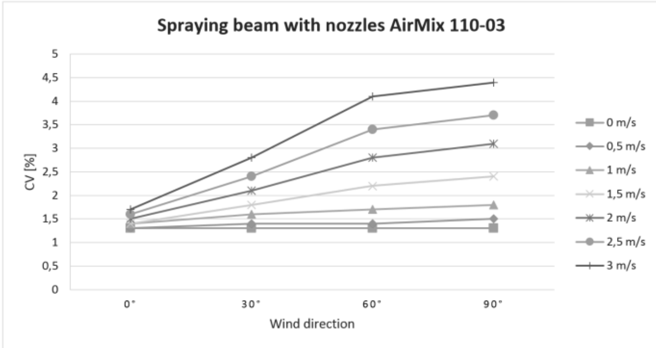

Fig. 5. Dependence of CV index value on wind direction for "virtual" spraying beam with AirMix 110-03 nozzles

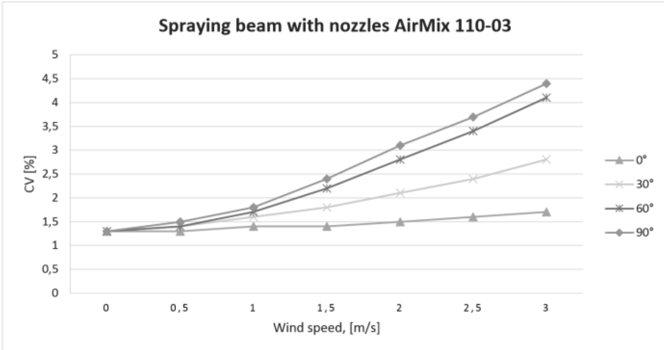

Fig. 6. Dependence of CV index value on wind speed for "virtual" spraying beam with AirMix 110-03 nozzles

The analysis of the results in Table 2 indicates that the influence of the wind direction and its speed on the CV index values determined for the "virtual" spraying beam is also similar for all three types tested. An increase in the angle of the wind direction or its speed results in the increase of the CV index value. All dependencies between the CV index for the beam and the wind direction and speed are close to the linear ones.

The lowest CV index values were obtained for the spraying beam equipped with AirMix 110-03 ejector nozzles. In the entire range of studied changes in wind direction (0 ÷ 90 °) and changes in its speed (0 ÷ 3 m/s), none of the CV index values exceeded 5%, which confirms its exceptional resistance to drift. In practice, this means that when spraying at a wind speed lower than or equal to 6 m/s, the permissible CV index value of 10 is not exceeded.%.

For the spraying beam equipped with the anti-drift AZ-MM 110-03 nozzles, the values of the CV index were obtained from the point of view of the quality of the spray. In the entire range of wind direction and wind speed changes, none of these values exceeded 9%, although they are about twice as high as the corresponding values for a beam equipped with AirMix 110-03 nozzles. It also confirms good resistance to drift in the tested range of changes in wind direction and speed.

Definitely the least favorable values of the CV index were observed for the spraying beam equipped with standard RS-MM 110-03 nozzles. Permissible CV index values (10%) were not exceeded only for wind speeds lower than 2 m/s, which is also confirmed by the manufacturer's recommendations.

Similarly as in the case of dependencies for single nozzles, it was also observed that the intensity of the wind speed increases as the angle of direction increases. For angles of 0 ° and 30°, the influence of wind speed is much lower than for angles of 60 ° and 90°.

CONCLUSIONS

Based on the analysis of the obtained results it was found that:

- wind direction and speed significantly influence the values of transverse irregularity index of CV liquid fall, both for individual nozzles and spraying beam. An increase in the angle of the wind direction or its speed causes an increase in the value of the CV index,
- the influence of wind speed on the values of the CV index for individual nozzles and the spraying beam depends on the angle of the wind direction. The greatest influence of wind speed was recorded for the angles of 60 ° and 90 °,
- high value of the CV index for a single nozzle does not mean that the value of the CV index for the spraying beam will exceed the limit value,
- the highest resistance to drift is characteristic of ejector nozzles AirMix 110-03 in the whole range of studied changes of wind direction and speed. For the spraying beam equipped with these nozzles, the largest CV value did not exceed 5 %,
- the permissible values of the CV index in the whole range of changes in direction and wind speed have not been exceeded also for the spraying beam equipped with anti-drift AZ-MM 110/03 nozzle,
- standard RS-MM 110-03 nozzles should not be used for spraying in conditions where the wind speed exceeds 2 m/s.

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