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ASSESSMENT OF THE USEFULNESS OF PATTERNATORS FOR THE CONTROL OF THE TECHNICAL STATE OF THE CROP SPRAYERS IN USE

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ABSTRACT

The paper presents the results of studies on spray nozzles, placed on a spray boom, hanging over a patternator. It was found out that when the location of particular nozzles is changed, the variation coefficient of distribution of the fall of the sprayed liquid (C.V.) changes as well. The change of C.V. is especially high for the nozzles which are technically worn out. The studies showed that while testing the nozzles on a patternator, the microclimate in the area of the site undergoes a change.

Key words: patternator, slit nozzle, distribution of the fall of the sprayed liquid, coefficient of variation, single nozzle flow rate.

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INTRODUCTION

Growing utilisation of the chemical agents for plant protection increases the social fear about the state of the natural environment. For these reasons, measures are taken in Poland to test the technique of performing the treatments and of the turnover of the plant protection preparations.

The law on plant protection treatments (*Journal of Law* No. 90 from 1995) and the decree in the matter of the detailed rules for carrying out the testing of the equipment for plant protection agent use (*Journal of Law* No. 20 from 1999) are a reflection of the undertaken measures. A detailed range of the testing was specified in the attachment to the decree, which presents the procedures and methods binding during the control of the technical conditions of the sprayers in use [7]. It was assumed that the manner of control will have an educational character, and the method of measurement will be reliable, repeatable and useful for the agricultural practice.

The procedures given in the control include about 40 measurements and estimations, performed on the basis of a subjective visual method. An estimation of the state of the sprayers through the measurements on a patternator is treated as especially important for the improvement of plant protection treatments. This measurement makes it possible to calculate the general coefficient of variation of distribution of the fall of the sprayed liquid (C.V.) for the spray boom.

PURPOSE AND SCOPE

The purpose of the studies was to determine the practical usefulness of patternators at the station testing the sprayers in use. Because of common use of flat spray nozzles, forming a symmetrical flow of liquid, in the spray booms the estimation was limited to this type of nozzles. It was assumed that C.V. for the transverse distribution of the fall of the sprayed liquid was not a sufficient indicator for the prediction of the quality of the plant protection treatments.

The above restrictions are connected with the fact that crop sprayers use exchangeable, non-certified nozzles of different degrees of wear. These sprayers are, in our conditions, usually fixed in single and not multiple nozzle bodies. According to the principles of proper spraying technique, in an agrotechnical period this type of sprayers are used which ensures a spectrum of drop characteristic of the kind of pesticide. This procedure causes that during the following change of nozzles, their position on a boom can undergo a change in relation to its position during the check. A possibility of such a change is also probable after the winter period, while preparing the sprayer for use. Consequently, there is a necessity of determining the coefficient of variation of the spray distribution for a given placement of nozzles on the spray boom.

In the formulated research problem it was considered particularly important to show whether C.V. of the spray distribution of the sprayed liquid changes with the change of the position of the nozzles on the spray boom and when the other conditions of the measurement are kept. The studies comprised a selected segment of the spray boom. They also estimated the whole procedure of testing the spraying quality of a patternator, considering preparations, performance and completion of the measurement.

METHODS

The studies were carried out on the site (see figure 1), which was a properly prepared 4 metres' fragment of a patternator (by Holder company). The site was situated in a closed room. The conditions of the studies are characterised in tab. 1. The patternator surface made of pieces of stainless sheet metal 1500 mm in length was shaped in grooves with the spacing of 100 mm and the decline angle in the direction of the measurement vessels of 5°.

Of the total number of 40 grooves on the measured width of the patternator, 20 which were placed in the central part (basic width) were estimated. The basic width of the studied patternator (2.0 m or 20 grooves) follows from the number of 5 nozzles placed on the spray boom. The studies considered two types of slit nozzles with the spray angle of 110°, which were placed 500 mm over the patternator. The nozzles were fixed with the spacing of 500 mm, in typical trunks of nozzle bodies ensuring 8° deviation of the surface of liquid spraying from the axis of the longitudinal spray boom.

Figure 1. Scheme of measurement site: *a)* general view: *1* – manometer, *2* – spray boom with slit nozzles, *3* – patternator; *b)* vertical surface of liquid spray by slit nozzles

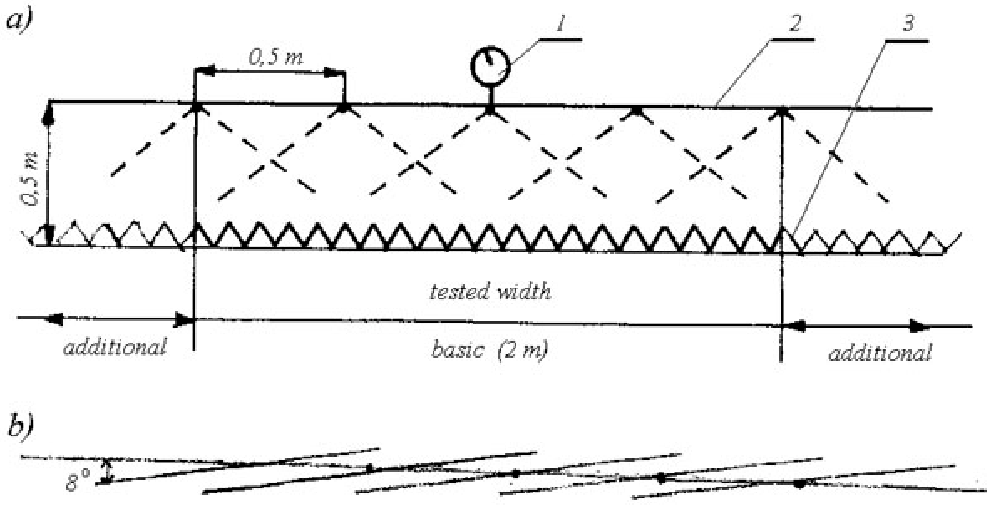

Table 1. Characterisation of the conditions of assessments

No.	Specification	Measure units	Type of nozzle	
			KZK Kranj	TTD Jet
1.	Patternator (manual) HOLDER			
	– length of patternator	mm	1500	1500
	– spacing of grooves	mm	100	100
	– measurement vessels 500 cm^3 of scale	cm^3	10	10
2.	Number of tested nozzles	number	5	5
3.	Material for nozzles		brass	polymer
4.	Amount of work till the test	hours	50	250
5.	Location of spraying surface for each nozzle (to the boom axis)	°	8	8
6.	Spraying angle	°	110	110
7.	Nominal flow rate	dm^3/minute	1.48	1,5
8.	Flow rate in tests	dm^3/minute	1.74	1.60
9.	Increase of flow rate	%	18	7
10.	Spacing of nozzles on the spray boom	mm	500	500
11.	Height of nozzles over patternator	mm	500	500
12.	Working pressure	MPa	0.3	0.3
13.	Room temperature			
	– before the tests	°C	13.5	13.5
	– during the tests	°C	11.5	11.5
14.	Relative humidity			
	– before the tests	%	71	71
	– during the tests	%	76	76

The studies made use of a complete, new sprayer "Pilmet 312", in which the work of all the units was checked and adjusted. The nozzles were fixed in the final section of the spray boom, where a legalised two-range manometer was installed, with a scale of 0.01 MPa pressure. The spray mixture was pure water taken from the spray tank. The measurements were taken with the working pressure of 0.3 MPa. In order to ensure the reliability of the measurements, the studies used the nozzles which were in common use and which were randomly dismounted from the nozzles in the Lublin area (Poland).

The positions for each type of nozzles on the spray boom were changed three times, and marked as P_1, P_2, P_3. For each position of the nozzles the measurements of the volume of the fall of the sprayed water in the measurement vessels were repeated many times. The analysis considered the results of the measurements where the sum of volume of the fall of the sprayed water collected in 20 measurement vessels did not differ by more than 10 cm^3.

The calculations made use of the statistical package of applications Microsoft Excel 7.0, where the following were calculated: standard deviation, variation coefficient (C.V.), asymmetry coefficient (slant). During the studies, measurements of relative air humidity were taken (on the height and distance from the patternator of 2 m), using an aspiration Assmann psychrometer TZ 9.

RESULTS

Two types of nozzles (table 1) tested in the studies were characterised by similar construction and nominal unit output and were differentiated in the kind of material from which they were made as well as the time of exploitation. The two latter factors determine the degree of the wear of each of the examined nozzles, which is decisive of the quality of the sprayers' work and which is expressed in the flow rate.

An explicit estimation (table 2) of the quality of the sprayer's work through determining the C.V. is not possible since the value of this coefficient is determined by the sequence of placing the nozzles of the spray boom. The volume of the water falling to particular grooves changed after each change of the sequence of placing the nozzles on the boom. This had a direct effect on the value of the calculated coefficient of variation.

Table 2. Sum of the volume of the water sprayed by two assessed types of nozzles collected from the basic width of the patternator with three random changes of placing the nozzle on the spray boom

Number of measurement vessel on the basic width (acc. to figure 1)	Volume of water collected from patternator grooves to measurement vessels, with different sequence (test) of placing the nozzles on the spray boom (cm^3)					
	KZK Kranj type nozzles 11004 in a test of location			TTD Jet type nozzles RS 110 R in a test of location		
	P_1	P_2	P_3	P_1	P_2	P_3
1	383	327	330	265	277	273
2	320	293	315	280	310	297
3	246	293	340	310	293	303
4	273	330	340	295	287	313
5	283	320	345	285	280	327
6	407	420	460	275	280	357
7	277	383	460	265	253	317
8	310	353	320	305	263	320
9	317	343	285	300	297	307
10	360	390	300	325	303	300
11	427	380	535	325	303	333
12	407	380	335	305	320	313
13	303	290	315	290	310	310
14	310	253	305	285	317	277
15	353	293	440	315	320	310
16	287	293	350	315	310	290
17	330	357	345	300	300	273
18	290	313	325	305	300	313
19	270	293	300	280	293	303
20	250	273	260	270	287	273
Sum of fall, cm^3	6403	6580	7005	5895	5903	6110
Mean fall for measurement vessel, cm^3	320	329	350	295	295	305
Standard deviation	53.3	45.2	69.1	18.7	18.1	21.4
Coefficient of variation C.V.% for measurement vessels:						
1 to 20	16.6	13.6	19.7	6.3	6.1	7.0
6 to 15	14.9	15.3	23.7	6.8	8.0	6.6

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With similar unit outputs and symmetric spraying of the liquid by each nozzle, these differences should not occur, and the amount of the fall of the sprayed water collected from the 20 tested grooves should be similar. It follows from the studies that the volume of the fall of the water collected from particular grooves was differentiated and dependent on the sequence of placing the nozzles on the spray boom. This differentiation, expressed in C.V. was high for the exploited and worn out brass nozzles KZK Kranj (C.V. was 16.6%, 13.6%, 19.7%) and lower for the nozzles made of plastic, TTD Jet (C.V. was 6.3%, 6.1%, 7.0%). The character of the examined relations (table 2) did not change if the estimation considered the fall from the nozzles installed in three centrally placed spraying tips (the volume of the fall from the grooves, numbers 6 to 15). In this case the C.V. for the nozzles KZK Kranj was: 14.9%, 15.3%, 23.7%, and for the nozzles TTD Jet: 6.8%, 8.0%, 6.6%. The effect of changing the sequence of locating the nozzles on the regularity of the fall distribution of the sprayed water on the patternator surface is also illustrated in figure 2 and figure 3. The curves for the regularity of the fall are not comparable in any case.

Figure 2. Distribution of transverse fall of the sprayed liquid achieved on the patternator (manual) with successive tests of displacing the nozzles on the spray boom. Type of nozzle: KZK KRANJ 11004. Test: P_1: CV = 16.6%, P_2: CV = 13.6%, P_3: CV = 19,7%

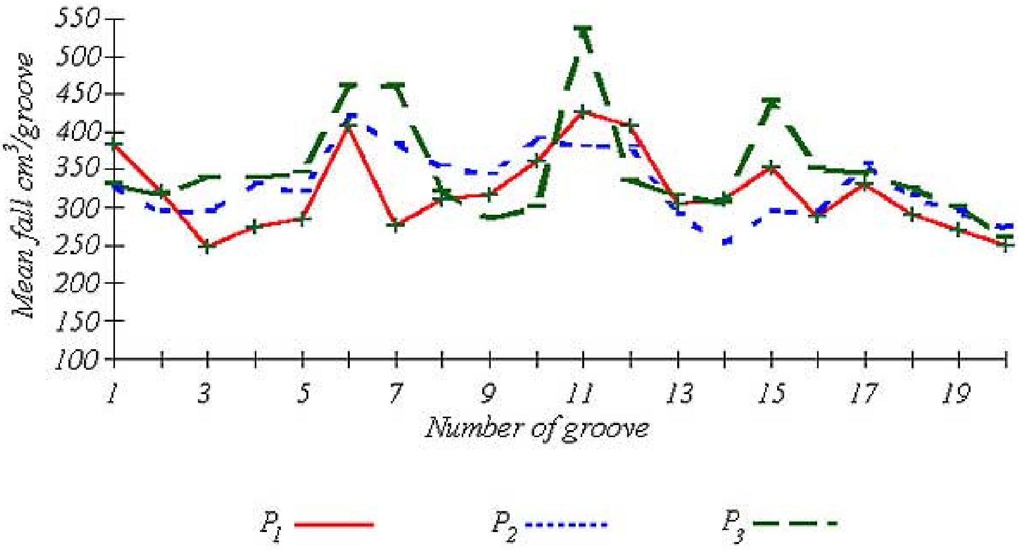
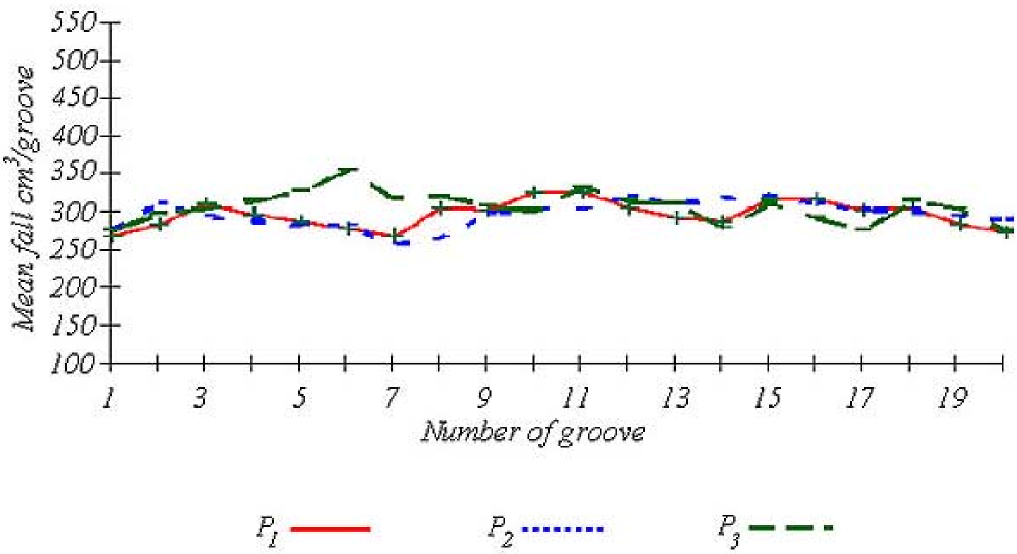


Figure 3. Distribution of transverse fall of the sprayed liquid achieved on the patternator (manual) with successive tests of displacing the nozzles on the spray boom. Type of nozzle: TTD Jet RS110R. Test: P_1: CV = 6.3%, P_2: CV = 6.1%, P_3: CV = 7.0%



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It is interesting to note that in the course of 45-minute-long measurements, the temperature in the surroundings of the patternator dropped by 2°C and the relative air humidity grew by 5%.

The general C.V. accepted in the instruction for the estimation of the working quality of the spray booms (with the slit nozzles fixed on them) can be influenced by the following factors: the height of placing the boom over the sprayed surface, the applied working pressure and also the regularity of the unit flow rate and asymmetry of the spray of the liquid by each of the examined nozzles.

The height of placing the spray boom and the range of the working pressure for all the types of nozzles in the sprayers recommended by the producer, are determined in the compulsory qualification tests. The testing procedures are regularised by law and obligatory for each producer of the sprayers. In these tests, according to ISO 5682-2, a patternator is necessary [5, 6]. The range of these tests does not include the measurement of the asymmetry of the fall of the sprayed liquid or the unit flow rate for particular nozzles. Determining the unit output and asymmetry coefficients is not recommended in control tests of the sprayers already in use.

The effect of unit output of the nozzles on the formation of C.V. (table 3) in relation to the asymmetry of the distribution of the sprayed liquid is analysed only theoretically. To this aim, the studies considered the work of five exploited flat slit spray nozzles with the same spraying angle. It was assumed that the nozzles marked as I, II, III, IV, V, were installed in typical spraying tips marked as A, B, C, D, E. The unit flow rate of the nozzles was accepted respectively as 1.0, 0.83, 0.97, 0.63, 0.87 dm^3 per minute. Besides, it was found out that the transverse fall distribution for each nozzle can be characterised by means of slant coefficient M (this coefficient expresses the asymmetry degree of the distribution of the examined values around the mean figure), which is: 0.0, 0.453 - 0.610, 0.166, - 0.389, respectively. In order to simplify the calculations, it was assumed that the total sum of the water fall from particular grooves of the patternator refers to a 30-minutes' fall.

The estimation was performed for three trials (P) of placing the nozzles on the spray boom:

P_k – control test, the nozzles placed according to the sequences of the markings. The result: C.V. = 13.9%,
P_p – keeping the extreme placement of the nozzles numbers I and V, and changing the places for the nozzle numbers II and III. The result: C.V. = 17.9 %,
P_d – all the spraying tips equipped with nozzle No. I with the slant coefficient M = 0.0. The result: C.V. = 0.0.

The test performed in this way makes it possible to state that the unit flow rate and maintaining the symmetry of the fall distribution of the sprayed liquid, for each nozzle, determine the spraying quality. That is why these measurers should constitute the basis for the testing of the technical condition of the nozzles.

It follows from the studies that expressing the work quality of the sprayer on the basis of the general coefficient of variation determined for the nozzles which have already been exploited and which are characterised by high differentiation of the flow rate and the distribution asymmetry of the sprayed liquid, is an improper indicator, especially controversial while formulating exploitation recommendations for the agricultural practice.

Table 3. Theoretical formation of the spraying parameters in the case of changing the location of the nozzles on the spray boom (scheme)

Control test (P_k)[x)]

Spraying tips	A					B				C				D				E					
No. of nozzle		I				II				III				IV					V				

Basic width of patternator considered in tests

Volume of fall from a nozzle to a groove of patternator

1	2	3	4	5	5	4	3	2	1																				
					2	2	2	3	4	4	3	2	2	1															
										1	3	3	4	4	4	3	3	2	2										
															1	1	2	2	2	3	3	2	2	1					
																				2	2	3	3	4	3	3	3	2	1

Sum of fall

1	2	3	4	5	**7**	**6**	**5**	**5**	**5**	**5**	**6**	**5**	**6**	**5**	**5**	**4**	**5**	**4**	**4**	**5**	**5**	**5**	**5**	**5**	3	3	3	2	1

Result of tests for P_k: mean unit expenditure of a nozzle 25.8, mean fall to a groove 5.1, **C.V. coefficient = 13.9%**

First test (P_p) – changing the location of nozzles: No. II and No. III in spray boom tips

				I					III					II					IV					V					
1	2	3	4	5	5	4	3	2	1																				
					1	3	3	4	4	4	3	3	2	1															
										2	2	2	3	4	4	3	2	2	1										
															1	1	2	2	2	3	3	2	2	1					
																				2	3	3	3	4	3	3	3	2	2

Sum of fall

1	2	3	4	5	**6**	**7**	**6**	**6**	**5**	**6**	**5**	**5**	**5**	**5**	**5**	**4**	**4**	**4**	**3**	**5**	**6**	**5**	**5**	**5**	3	3	3	2	2

Result of tests for P_p: mean unit expenditure of a nozzle 25.8, mean fall to a groove 5.1, **C.V. coefficient = 17.9%**

Second test (P_d) – only nozzles with the parameters of nozzle: No. I – slant coefficient = 0.0, **result: C.V. coefficient = 0**

				I					I					I					I					I					
1	2	3	4	5	5	4	3	2	1																				
					1	2	3	4	5	5	4	3	2	1															
										1	2	3	4	5	5	4	3	2	1										
															1	2	3	4	5	5	4	3	2	1					
																				1	2	3	4	5	5	4	3	2	1

Sum of fall

1	2	3	4	5	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	5	4	3	2	1

x) The grooves of the patternator with the spacing of 100 mm. The nozzles (marked as I, II, II, IV, V) fixed in the spraying tips, in the spacing of 50 cm and the height 50 cm over the patternator. Theoretical unit output and sums of falls.

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DISCUSSION

Introducing precise agriculture into practice also concerns the technique of crop protection. In these treatments a vital importance is attributed to limiting the doses of chemical agents for crop protection and assuring their precise distribution on the protected cultivated areas. These requirements can be fulfilled through the improvement of chemical preparations for crop protection and progress in the construction of equipment for their application. An important element of this process is improvement of the measurement technique and the methods of tests, which will enable sufficiently early statement of the present and possibly future technical defects and imperfections of the equipment. The tests should provide a possibility of performing measurements which will be explicit, repeatable, fully useful for the agricultural practice, and the ones which will not require high investments for the measurement stands.

At present, two basic methods of measuring the quality of the sprayers' work are used, which, according to the authors, comply with the methodical and utilitarian requirements. These methods consider an estimation of the spraying quality through determining the general C.V. on a patternator [2] or through a comparison of the currently found flow rate with the nominal flow [3]. There are also some authors who combine those two methods of measurement [4]. In Poland, in accordance to law (*Journal of Law* No. 20 from 1999), since 1999 the measurement should be carried out using the method of measuring the transverse flow distribution, but for realisation the method was accepted which determines the C.V. of the sprayed liquid fall, through the measurements on a patternator.

It follows from the test that obtaining the recommended (below 15%) coefficient of variation for the tested sprayer does not mean that in practice (as a result of the servicing work on the patternator) this coefficient will not be worse. The C.V. will be especially "flexible" with the exploited nozzles of high differentiation of unit output. Besides, in the period between the obligatory control tests of the sprayers whose booms were equipped with single and not multiple spraying tips, there is a greater danger of changing the location of the nozzles on the boom a few times. In such a case, transverse distribution of the sprayed liquid expressed by C.V. can undergo frequent changes and can be different from that provided in the documentation given to the farmer after the control tests of the sprayer.

This situation will not take place if the tests on the patternator are performed within the range which will make it possible to achieve the result stating that the variation coefficient given to the farmer will not be higher for any position of the nozzles on the spray boom. With the present range of studies, the farmers should control the quality of the spray on the patternator, after each displacement of the nozzles.

As compared to the brand new sprayers, the studies of the exploited ones limit the range of the possible uses of the patternator. In this case, the tests should be absolutely conducted in separate rooms and with particular precautionary measures. This is caused by the fact that it is not possible to state visually whether the sprayer was carefully washed. It follows from the presented results that the microclimate around the patternator undergoes changes, which is pointed at by the fact that the sprayed liquid vaporises, and the compounds in it spread in the air around. For these reasons, there is a possibility that the staff servicing the patternator (the site) will get in contact with the chemical poisonous agents spread through vaporisation or deflection of the liquid from the patternator. Besides, these tests are ecologically dangerous since big amounts of water used for washing the sprayer, and anticipated transmission of the water used for control tests to the farmers question the way in which this water is managed. For these reasons, the use of patternators creates a danger both for the workers and the environment. That is why testing the technical state of the nozzles is justified after they are dismounted from the spray boom.

For the above reasons, testing the technical state of the nozzles using the methods of measuring the flow rate, supplemented with determination of distribution asymmetry of the sprayed liquid in each nozzle, can be a perspective method. These measurements, which do not bring any ecological dangers and which can be performed in laboratory conditions, are a simple, explicit and practically useful method. The method is also cheaper in relation to the tests using a patternator. A patternator's price (the offers from 1999) ranges from 28 000 PZL (US$ 6500) for a manual patternator, to 64 000 PZL (US$ 15 000) for an electronic one, plus 77 000 PZL (US$ 18 000) for a tent where the measurements are performed. The measuring equipment for determination of the unit flow rate for particular nozzles is offered at the price of 28 000 – 32 000 PZL (US$ 6500 – 7600), and with a manual method to 5000 PZL (US$ 1200) [8]. Both measurement methods are comparable as for time consumption, but one can assume that with bad work organisation the measurement time with the method of determining the unit flow rate is longer by about 10 min for each of the tested nozzles. While estimating the technical state of the nozzles one should pay attention to the fact that it follows from the studies of the Industrial Institute of Agricultural Machinery in Poznan which were put into practice that new nozzles of famous companies keep both the unit flow rate of the liquid and coefficient of variation (C.V.), as compared to the nominal [1].

CONCLUSIONS

The method, which is now introduced in Poland, of controlling the technical state of field sprayers which have often been exploited for a number of years, disregards the method of measuring the flow rate for each nozzle and does not consider distribution asymmetry of the sprayed liquid. The binding method is based only on using a patternator for determination of the general variation coefficient for all the nozzles installed on the spray boom. It follows from the analysis that the tests on a patternator do not ensure the required repeatability of the measurements after changing the sequence of the installed nozzles on the spray boom. Therefore, the obtained positive results of tests on a patternator do not guarantee the performance of a crop protection treatment despite the calculation of liquid output for a sprayer (so-called sprayer calibration), in conversion to arable lands.
For the above reasons, EU experts' opinion should be regarded as proper that while testing new sprayers a patternator can be used only to determine the height of locating the spray boom for the nozzles working at optimum working pressure [6]. On the other hand, it can be stated on the basis of the presented results that because the quality criteria, including ecological, economic and utilitarian ones, are not satisfied, using patternators for testing the technical state of the exploited sprayers raises serious doubts. Further studies in this sphere should be continued in order to specify the views presented here.

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