THE COMPARISON OF THE NOZZLE INSPECTION METHODS IN FIELD CROP SPRAYERS: NOZZLE FLOW VS. SPRAY TRANSVERSE DISTRIBUTION – METHODOLOGY AND SOME RESULTS*

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Introduction: The European standards (EN 13 790-1, EN ISO 16122-2) and some national procedures for the inspection of field crop sprayers in use allow two methods of evaluation of the nozzles. In only a few countries both methods of the nozzle inspection - measurement of nozzle flow and transverse distribution – are used [Wehmann 2012]. In the majority of countries only measurement of the transverse distribution of the spray is carried out, with the coefficient of variation CV% as a measure of accuracy.

The comparison of the nozzle inspection methods have not been carried out in a direct way. Therefore, it is not known which of these methods is more rigorous, and if both methods could achieve the same results. In order to compare the stringency, costs and time-consuming of both inspection methods, the methodology of comparative tests have been elaborated. Then some trials were carried out.

Materials and Metods: The elaborated methodology describes how to compare and what criteria to use for the evaluation of methods of inspection nozzles in field crop sprayers. In the study, three types of Lechler nozzles were used (utilized for less than one hour): flat fan standard (LU 120-03) at 3 bar, flat fan air-injector (ID 120-03) and Twin flat spray air-injector compact nozzles (IDKT 120-03) at 4.5 bar. During the tests the electronic spray patternator SPRAYER TEST 1000 (PESSL Instruments, Austria) and the groove patternator (STABEN - "operator data readout") was used. The nozzle flow was measured by set of 20 scaled cylinders (SCHACHTNER of nominal capacity 2000 ml and accuracy 20 ml with HERBST nozzle adapters) and a ball flow-meter LURMARK.

For each of the evaluated method the time of each repeatable action was measured and the results of the measurements were noted (CV%, mean nozzle flow rate, the number of the cylinders with 10 ora 15% deviation from the mean and each nozzle flow rate). The gathered data allowed the calculation of an average time of the inspection of one nozzle depending on the type of the nozzle and the method used as well as binary and linear assessment of the test result.

The binary assessment expressed the result of the sprayer/nozzle inspection as „1" = inspection passed or „0" = inspection not passed.

The linear assessment expressed a percentage of fulfill the inspection criteria (eg. CV% or the maximum deviation from the nominal value of nozzle flow rate).

Example: For limit value of CV% or flow rate deviation = 10% (linear assessment = 100%).

Case 1: Measured value = 5% - the binary assessment is 1 (inspection is passed) and the linear assessment is 50%.

Case 2: Measured value = 15% – the binary assessment is 0 (inspection is not passed / failed), linear assessment is 150%.

The linear assessments answers whether the compared methods are equally "rigorous" or do they show the same „distance" from the limit value. The repeatability of measurements (for 4 repetitions) was evaluated by calculating the coefficients of variation.

The total cost of the sprayer inspection was calculated basing on: the time of one nozzle inspection, boom length and number of nozzles sets mounted on it, workshop worker salary and the number of inspections per year done in the workshop. The proportional use of buildings with other activities was assumed to calculate costs of buildings use and equipment amortization. The time of inspection of other sprayer elements was assumed basing on other experiments (25 minutes).

Flat fan nozzles (Fig. 1-3):
Standard (LU 120-03) @ 3.0 bar
Air-injector (ID 120-03) @ 4.5 bar
Air-injector - Twin stream (IDKT 120-03) @ 4.5 bar

Patternators working in steps:
With electronic data sampling - PESSL Instruments (Austria) (Fig. 4)
With operator data readout - STABEN (Poland) – 3 m width (Fig. 5)

Volume measuring devices:
Measuring cylinders (20 pcs - 2000 ml) – SCHACHTNER (Fig. 6)
Ball flow-meter - LURMARK (Fig. 7)


Fig. 1.

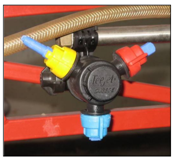
Fig. 2.


Fig. 3.

Fig. 4.


Fig. 5 a.

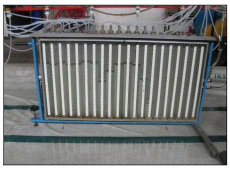
Fig. 6 a.


Fig. 6 b.

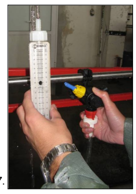
Fig. 7.


Fig. 5 b.

Results: The results of measurements followed by binary, linear and repeatability assessments are presented in the tables 1,2 and 4. The costs of inspection depending on the method of nozzle evaluation method are contained in table 3.

Table 1. Spray transverse distribution uniformity evaluation – coefficient of variation (CV%) - binary and linear assessment and repeatability.

Nozzle	CV%	Linear (%)	Binary	Repeat (CV%)
Electronic patternator PESSL – experiment I				
LU-120-03	10.46	104.6	0	2.86
IDKT-120-03	8.69	86.9	1	0.24
ID-120-03	6.41	64.1	1	6.24
Electronic patternator PESSL – experiment II*				
LU-120-03	21.6	216.3	0	14.81
IDKT-120-03	10.5	105.3	0	3.03
ID-120-03	9.5	95.3	1	1.36
Patternator – operator readout STABEN – experiment II*				
LU-120-03	15.5	155	0	2.43
IDKT-120-03	15.7	157	0	5.73
ID-120-03	14.3	143	0	7.39

* In experiments I and II the sequence of nozzles on the boom was changed.

Table 2. Spray transverse distribution uniformity evaluation - amount of grooves (cylinders) containing volume outside of limit deviation from mean – binary and linear asessment and repeatability.

Nozzle	Out of limit	Linear (%)	Binary	Repeat (CV%)
Electronic patternator PESSL – experiment I – limit ±10%				
LU-120-03	33.0	270.5	0	4.76
IDKT-120-03	24.7	205.6	0	1.91
ID-120-03	8.5	70.8	1	17.65
Electronic patternator PESSL – experiment II* – limit ±15%				
LU-120-03	37.5	312.5	0	10.24
IDKT-120-03	14.5	120.8	0	7.71
ID-120-03	9.0	75.0	1	7.86
Patternator – operator readout STABEN – experiment II* – limit ±15%				
LU-120-03	20.3	168.8	0	4.09
IDKT-120-03	12.8	106.3	0	6.50
ID-120-03	4.8	39.6	1	37.60

* In experiments I and II the sequence of nozzles on the boom was changed.

Table 3. The simulated cost of a field crop sprayer inspection (1 worker) depending on nozzles inspection method, boom length and number of nozzles sets mounted on, worker monthly salary and number of inspections done in a workshop per year.

Inspection method	Monthly salary = 1600 PLN					Monthly salary = 3600 PLN				
	Nunber of inspections per year					Number of inspections per year				
	100	200	500	1000	1500	100	200	500	1000	1500
	Field crop sprayer – boom 12 m – 1 set of nozzles mounted on									
Electronic paternator	90.15	49.45	25.03	18.53	14.99	100.01	59.31	34.89	28.39	24.84
Paternator – operator read	42.96	26.89	21.19	15.47	13.57	55.15	39.08	33.37	27.66	25.75
Measuring cylinders	48.17	30.67	23.88	17.88	15.88	62.99	45.49	38.70	32.70	30.70
Ball flow-meter	17.94	12.84	9.78	10.50	9.33	26.66	21.56	18.50	19.22	18.05
	Field crop sprayer – boom 36 m – 5 sets of nozzles mounted on									
Electronic paternator	118.43	77.73	53.31	44.04	40.49	160.12	119.42	95.00	85.73	82.19
Paternator – operator read	90.21	74.14	63.80	58.08	56.18	155.59	139.52	129.18	123.47	121.56
Measuring cylinders	137.08	119.58	104.07	98.07	96.07	252.03	234.53	219.01	213.01	211.01
Ball flow-meter	36.86	31.76	28.70	27.57	26.39	66.88	61.78	58.72	57.59	56.41

Table 4. Nozzle flow evaluation – deviation from nominal value – number / percentage of nozzles with flow deviated more than 10% from the nominal value.

Nozzle (-120-03)	Deviation from nominal value – number / percent of nozzles *Nominal flow: LU = 1,19 l/min ; IDKT & ID = 1,46 l/min*					Mean nozzle flow (all nozzles on the boom)		
	<90% (pcs)	>110% (pcs)	Total (pcs)	Total (%)	Repeatability **(CV%)**	Mean (l/min)	**Deviation (%)**	**Repeatability (CV%)**
Measuring cylinders SCHACHTNERI								
LU	**0.25**	**10.00**	**10.25**	**42.7**	**14.43**	**1.28**	**8.50**	**1.16**
IDKT	**0.25**	**7.00**	**7.25**	**30.2**	**39.47**	**1.58**	**7.90**	**1.21**
ID	**4.25**	**1.25**	**5.50**	**22.9**	**20.33**	**1.41**	**9.80**	**0.77**
Ball flow-meterI								
LU	**0,00**	**2,50**	**2,50**	**10,4**	**44.72**	**1.28**	**7.95**	**0.68**
IDKT	**0,25**	**5,00**	**5,25**	**21,9**	**49.26**	**1.60**	**9.46**	**1.04**
ID	**1,00**	**19,75**	**20,75**	**86,5**	**2.09**	**1.81**	**26.48**	**2.56**
Electronic patternator PESSL – experiment I								
LU						**1.18**		**1.04**
IDKT						**1.39**		**0.51**
ID						**1.45**		**1.57**

Conclusions:

1. The comparison of the nozzle inspection methods may be done in by the evaluation of repeatability of the measurements and the costs of the inspection.
2. The results of the flow or transverse distribution measurements may be expressed as simple binary Yes/No assessment or as a linear assessment giving the answer: which one of the methods is more rigorous or how far is the measurement result from the limit value.
3. The choice of the method of nozzle inspection may depend on the number of inspections done in the workshop.

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