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EXPERIMENTAL RESEARCH ON THE DETERMINATION OF FUNCTIONAL AND QUALITATIVE INDICES OF HYDRAULIC NOZZLES THAT EQUIP SPRAYING MACHINES

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Abstract

Obtaining an appropriate effectiveness with minimal expenses of chemical treatments is possible only if they are executed with superior qualitative indices and very precisely in terms of ensuring the stability of the solution norm administered per treated surface unit.

Achieving a biological effectiveness of a spraying treatment is conditioned by ensuring the minimum optimal number of drops per treated surface unit.

The reduction of liquid norms per hectare is possible, however, only under the conditions of maintaining an equal or greater agro-availability of the spraying solution, by using studied spraying systems where the size of the drops can be controlled and directed, as well as their distribution on the plants.

The main objective of the experimental determinations was the determination of some functional and qualitative indices that characterize different types of hydraulic nozzles used in practice.The obtained results will allow a comparative analysis of the effectiveness of the treatments carried out with these nozzles, in terms of the biological effect.

***Key words**: sprinkling machines, nozzles, liquid flow*

INTRODUCTION

The current orientation in combating plant diseases and pests is to integrate chemical treatments into the complex of measures aimed at contributing to the prevention and combating of diseases and pests in the most effective way, without harming useful fauna and flora and implicitly to humans, in order to ensure and the continuous increase of agricultural production (Glodeanu M., 2000; Stahli W. and T. Bungescu, 2005; Stahli W. and T. Bungescu, 2006).

Obtaining a biological effectiveness of a spraying treatment is conditioned by ensuring the minimum optimal number of drops per treated surface unit, as follows: for systemic insecticides 20-30 drops/cm^2; for contact insecticides 50-70 drops/cm^2; for fungicides 50-70 drops/cm^2 (Glodeanu M., 2000; Neagu T., 1982; Rus F., 2000; Stahli W., 2003; Stahli W. and T. Bungescu, 2005).

The increase in the degree of spraying allowed the significant reduction of the liquid norm and implicitly the corresponding increase in the effectiveness of the spraying treatments (Planas de Marti S., 2000). The solutions used in this case have a higher concentration of active substance, but the dose of active substance must remain constant regardless of the amount of water that is distributed (Stahli W. and T. Bungescu, 2005).

Thus, it can be considered that a given treatment can be performed under conditions of equal efficiency with various norms of liquid per hectare, if the minimum number of drops is achieved on the previous square content (Falchieri D. and A. Cesari, 1993; Glodeanu M., 2000; Stahli W. and T. Bungescu, 2006).

The reduction of the liquid norms per hectare is possible, however, only under the conditions of maintaining an equal or greater availability of the spraying solution, by using studied spraying systems where the size of the droplets can be controlled and directed, as well as their distribution on the plants (Costache N. and E. Luca, 1982, Glodeanu M., 2000; Naghiu Livia, 2008; Rus F. et al., 2000; Stahli W. and T. Bungescu, 2006; Knott Cathy, 1994).

MATERIALS AND METHODS

The main objective of the experimental determinations was the determination of some functional and qualitative indices that characterize different types of hydraulic nozzles used in practice (liquid flow through the nozzle; nozzle flow coefficient, droplet tip angle; droplet distribution uniformity on working width, degree of drop coverage).

For the tests in laboratory conditions, different types of nozzles produced by Teejet were chosen (XR11001, DGJ60-11003).

The obtained results will allow a comparative analysis of the effectiveness of the treatments carried out with these nozzles, in terms of the biological effect.

As a result of the proposed objectives, the need to correctly establish the environmental impact - biological effectiveness correlation and drift reduction measures in order to reduce the environmental impact also resulted.

1. *The actual flow of liquid through the nozzles* (the theoretical one being specified according to the symbol inscribed on the respective nozzle, in gal/min – gallons per minute; 1 gal/min=3.8 l/min).

The determinations are made for different usual values of the working pressure (fig. 1).

The adjustment of the pressure at which the determination is made is made with the help of the safety valve (5).

The actual flow rate provided by the nozzle is measured using a graduated cylinder (7), and the time the nozzle flows inside the graduated cylinder is controlled by means of a shutter system (9) and a time relay (8).

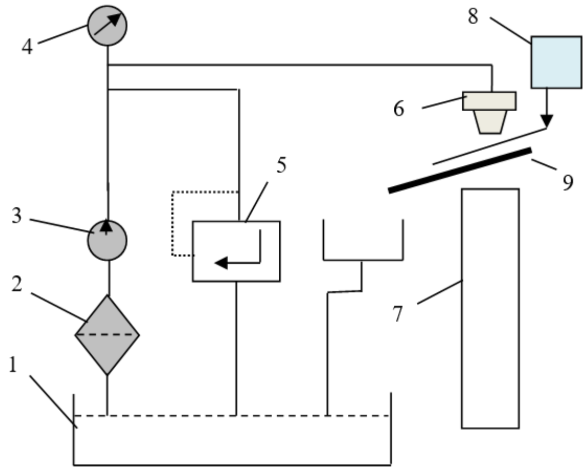

Figure 1. Scheme of the device for determining the flow of liquid through the nozzle: 1-tank; 2-filter, 3-pump; 4-manometer; 5-safety valve; 6-nozzle; 7-graduated cylinder; 8-time relay; 9-shutdown system.

2. *The nozzle flow coefficient (μ)* represents the ratio between the actual liquid flow rate (Q_r) passing through the nozzle (the measured one) and the theoretical flow rate (Qt). It is calculated with the relationship (Rus F. et al., 2000):

$$\mu = \frac{Q_r}{Q_t} \quad (1)$$

3. *The angle of the droplet jet* (it is specified according to the symbol inscribed on the respective nozzle).

4. *The uniformity of the distribution of the drops on the working width* is determined by collecting the drops of the jets on a platform made up of 100 mm troughs, with a graduated cylinder placed next to each trough (fig. 2).

Drops are collected for 1 min., time measured with a timer. By graphically representing the volume of liquid captured in the unit of time, in each graduated cylinder the distribution diagram of the drops on the working width of the nozzle (or of a section of the spraying boom) is obtained (Merkmale Sprith, BBA, 1994).

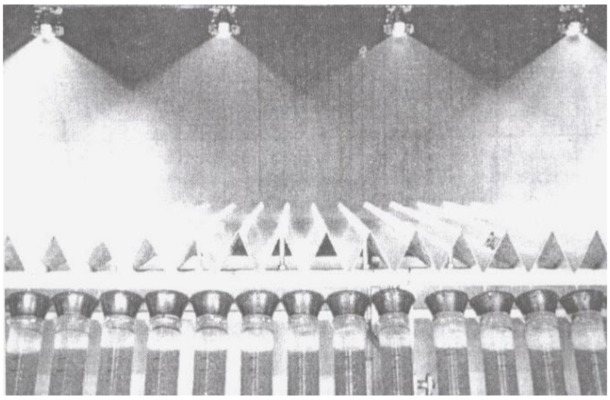

Figure 2. Stand with 100 mm gutters for determining the uniformity of the transverse distribution of the sprayed liquid at the spraying boom in a horizontal plane.

Based on the results obtained (after collecting the amount of liquid from each graduated cylinder), the average amount of liquid in the cylinders can be calculated using the relationship:

$$\bar{x} = \frac{\sum x_i}{n} \qquad (2)$$

where, x_i is the amount of liquid in ml, collected in each of the cylinders.

The quality of the cross-sectional distribution is evaluated based on the coefficient of variability (CV) expressed with the relationship (Stahli W., 2003):

$$CV = \frac{s}{\bar{x}} 100\ \% \qquad (3)$$

where s is the standard deviation:

$$s = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}}$$

The assessment of the quality of the transverse distribution will be made according to the following specifications (BBA, 1994; British Crop Protection Council (BCPC), 2008):

- CV< 7% - good uniformity of the lateral distribution;
- CV=7...9% - acceptable uniformity of the lateral distribution;
- CV>9% - unacceptable uniformity of the lateral distribution.

5. *The degree of droplet coverage*; in order to be able to determine the values of this index (which characterize the quality of a phytosanitary treatment), the jet of drops provided by the nozzles subject to experimentation will be dispersed towards a flat surface, on which glass catchers (lamellas) are placed at distances determined by the spray head.

The degree of droplet coverage is the ratio of surface area covered by the traces of drops and the total surface on which it is sprayed. This index is calculated with the relationship (Rus F et al., 2000):

$$G_a = \frac{\pi}{4A}\left(d_1^2 n_1 + d_2^2 n_2 + ... + d_n^2 n_n\right) \cdot 100 \qquad (4)$$

where: $d_1...d_n$ represent the diameters of the droplet traces in μm; $n_1...n_n$ – the number of drops in each size class.

Functional and qualitative indices will be determined for the following types of nozzles:

- *Extended Range Flat Spray Tipes*: XR Teejet 11001
- *Drift Guard Twin Flat Spray Tipes*: DGJ60-11003.

RESULTS AND DISCUSSIONS

The results of the experiments concerning XR Teejet 11001 nozzles

1. Actual liquid flow rate through the nozzle

The results of the experiments are presented in table 1.

2. Nozzle flow coefficient

The results of the experiments are presented in table 2.

3. Uniformity of droplet distribution over the working width

The results of the experiments are presented in table 3.

Table 1. Actual and theoretical flow rates for XR Teejet 11001 nozzles

XR Teejet 11001					
Flow rate (l/min)	Working pressure (bar)				
	1,5	2	2,5	3	4
Real flow rate (l/min)	0,266	0,324	0,365	0,387	0,447
Theoretical flow rate (l/min)	0,280	0,320	0,360	0,390	0,450

Table 2. Flow coefficient values for XR Teejet 11001 nozzles

Working pressure (bar)	1,5	2	2,5	3	4
Flow coefficient values **XR Teejet 11001**	0,950	1,012	1,013	0,992	0,993

Table 3. Assessment of the quality of the transverse distribution for XR Teejet 11001 nozzles

Working width (dm)	1	2	3	4	5	6	7	8	9	10
Flow rate per working width (ml/min) for: p = 1,5 bar, 2 bar, 2,5 bar, 3 bar, 4 bar	273	266	271	276	285	289	291	283	273	275
	311	302	303	309	318	329	322	313	322	327
	355	350	348	343	353	364	372	368	353	350
	386	380	373	375	382	385	392	401	405	397
	444	439	436	441	452	447	459	463	469	458
Working pressure	p = 1,5 bar		p = 2,0 bar		p = 2,5 bar		p = 3,0 bar		p = 4,0 bar	
x	278,2		315,6		355,6		387,6		450,08	
s (%)	8,29		9,50		9,34		10,85		11,13	
CV (%)	2,98		3,01		2,62		2,80		2,46	
U_{dl} (%)	**97,01**		**96,99**		**97,38**		**97,20**		**97,54**	
Appreciation	Very good		Very good		Very good		Very good		Very good	

It can be seen that these universal type nozzles provide a very good quality of the transverse distribution this indicator having values between 96,99% and 97,54% (having in view the value of coefficient of variability, for all the values of working pressures:1.5; 2.0; 2.5; 3.0 and 4.0 bar).

Following experiments in laboratory conditions it was found that these nozzles have the advantage that, being mounted at a distance of 50 cm on the boom, they achieve very high droplet distribution uniformity over the working width (approx. 98%), even if the working height of the boom varies within very wide limits (between 25 and 100 cm).

4. The degree of droplet coverage

The results of experiments on achieving the degree of droplet coverage (G_a) for the XR Teejet 11001 nozzles are presented in table 4.

From the analysis of the results obtained from the experiments, the following can be noted:

- with increasing pressure, the value of the coverage degree increases (due to the increase in the degree of spraying), obtaining very fine droplets, thus ensuring a fine and very fine sprinkling (F; VF);
- in reality, droplets with a diameter value below 100 µm (i.e. those that confer positive qualities regarding the biological effect) have low energy, their trajectory being strongly influenced by air currents (drift, thermal effect), and their duration of existence is very short (evaporation occurring before they reach the intended target); the drift phenomenon causes appreciable losses of pesticide substances, producing contamination of crops or neighboring perimeters, surface waters, etc., thus constituting an important problem for environmental protection.

Table 4. Results of experiments on achieving droplet coverage for XR Teejet 11001 nozzles

Nozzle type	No. of drops	Droplet size spectrum (μm)	G_a (%)	Type of spraying
p = 1,5 bar				
XR Teejet 11001	8	Φ=500	3,38	***F***
	127	Φ=120		
	195	Φ=50		
p = 2,0 bar				
XR Teejet 11001	7	Φ=500	3,38	***F***
	141	Φ=120		
	212	Φ=50		
p = 2,5 bar				
XR Teejet 11001	6	Φ=500	3,54	***F***
	184	Φ=120		
	252	Φ=50		
p = 3,0 bar				
XR Teejet 11001	4	Φ=500	3,55	***F***
	103	Φ=120		
	87	Φ=50		
p = 4,0 bar				
XR Teejet 11001	1	Φ=450	4,26	***VF***
	312	Φ=120		
	298	Φ=50		

Legend:
*F – fine spray
*VF – very fine spray

The results of the experiments concerning the nozzles DG J60-11003

1. Actual liquid flow rate through the nozzle

The results of the experiments are presented in table 5.

2. Nozzle flow coefficient

The results of the experiments are presented in table 6.

3. Uniformity of droplet distribution over the working width

The results of the experiments are presented in table 7.

In order to be able to carry out a comparative analysis regarding the appreciation from the point of view of the value of the coefficient of variability, it can be found that **DG** J60-11003 nozzles are characterized by lower values of the coefficient of variability compared to XR Teejet 11001 nozzles.

It can be seen that these type of nozzles provide a very good quality of the transverse distribution this indicator having a value of approx. 99%

Liquid distribution graph over the working width for the XR Teejet 11001 and DG J60-11003 nozzles is presented in figure 3.

Table 5. Actual and theoretical flow rates for DG J60-11003 nozzles

DG Twinjet J60-11003					
Flow rate (l/min)	Working pressure (bar)				
	2	2,5	3	3,5	4
Real flow rate (l/min)	0,95	1,12	1,23	1,34	1,40
Theoretical flow rate (l/min)	0,96	1,08	1,18	1,27	1,36

Table 6. Flow coefficient values for DG J60-11003 nozzles

Working pressure (bar)	2	2,5	3	3,5	4
Flow coefficient values **DG J60-11003**	0,98	1,03	1,04	1,05	1,02

Table 7. Assessment of the quality of the transverse distribution for DG J60-11003 nozzles

Working width (dm)	1	2	3	4	7	8	9	10
Flow rate per working width (ml/min) for: p = 2 bar, 2,5 bar, 3 bar, 4 bar	946	952	954	967	973	969	955	949
	1067	1071	1073	1089	1093	1084	1074	1067
	1169	1163	1158	1171	1190	1169	1165	1168
	1343	1340	1342	1350	1384	1371	1365	1349
Working pressure	p = 2,0 bar		p = 2,5 bar		p = 3,0 bar		p = 4,0 bar	
x	963,0		1080,4		1174,3		1359,8	
s (%)	13,61		11,12		13,73		16,84	
CV (%)	1,41		1,02		1,16		1,23	
U_{dl} (%)	**98,59**		**98,98**		**98,84**		**98,77**	
Appreciation	Very good		Very good		Very good		Very good	

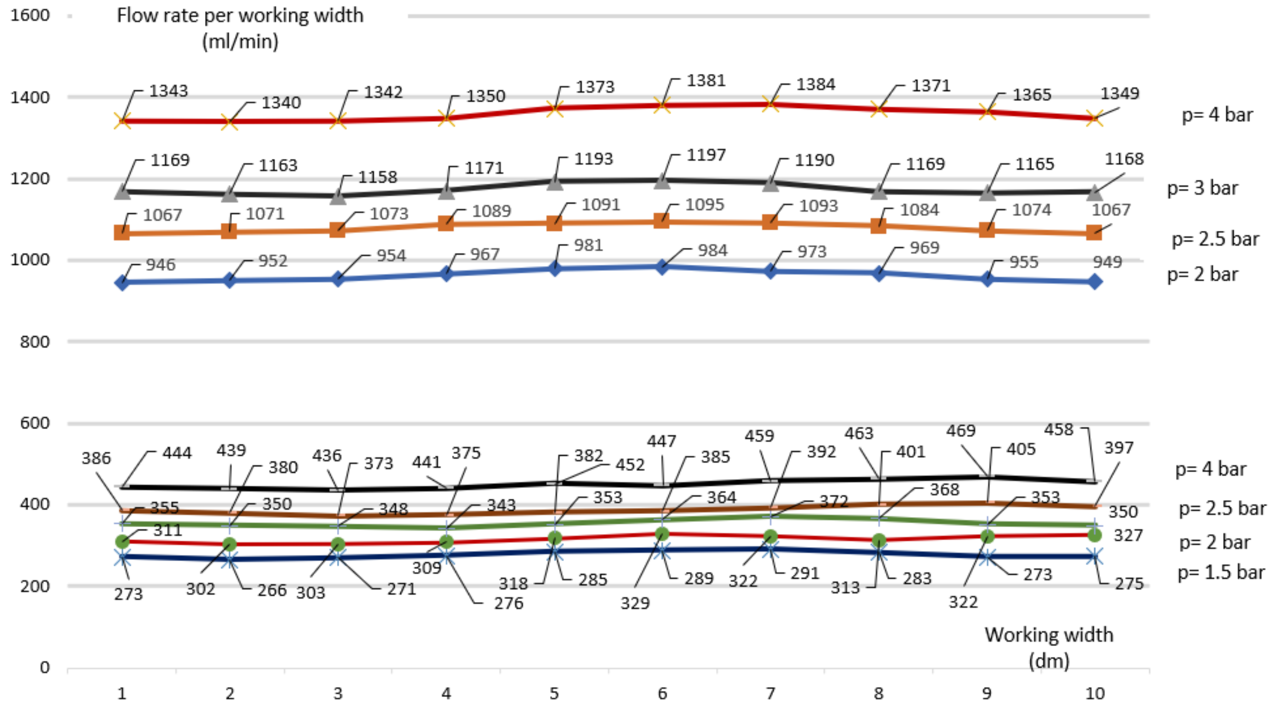

Figure 3. Liquid distribution graph over the working width for the XR Teejet 11001 and DG J60-11003 nozzles.

Analysis of the graphic representation highlights a very good appreciation of the quality of the transverse distribution.

Although the deviations from the average amount of liquid in the graduated cylinders are greater in the case of drift guard nozzles (up to 17%) compared to XR Teejet nozzles, the amount of substance lost through drift when spraying with sprayers with anti-drift nozzles is much lower (the value of losses being almost half the value corresponding to universal nozzles).

4. The degree of droplet coverage

The results of experiments on achieving the degree of droplet coverage (G_a) for the

DG J60-11003 nozzles are presented in table 8.

Table 8. Results of experiments on achieving droplet coverage for DG J60-11003 nozzles

Nozzle type	No. of drops	Droplet size spectrum (µm)	G_a (%)	Type of spraying
p = 2,0 bar				
DG J60-11003 nozzles	0,5	Φ=1000	1,96	***C***
	6	Φ=500		
	10	Φ=225		
p = 2,5 bar				
DG J60-11003 nozzles	2	Φ=500	2,54	***M***
	39	Φ=250		
	31	Φ=100		
p = 3,0 bar				
DG J60-11003 nozzles	1,5	Φ=500	2,82	***M***
	46	Φ=250		
	35	Φ=100		
p = 4,0 bar				
DG J60-11003 nozzles	2	Φ=500	1,96	***M***
	30	Φ=225		
	40	Φ=110		

Legend:
*M – medium spray
*C – coarse spray

From the analysis of the results obtained from the experiments, the following can be noted:
- that this type of nozzles ensure a coarse and medium sprinkling (C; M);
- in practice coarse and medium sprinkling is preferred in order to avoid the drift phenomenon, which can represent an important problem for environmental protection (the most effective measure to reduce losses due to drift and to ensure an acceptable degree of droplet coverage).

CONCLUSIONS

The results of the experiments carried out on the XR Teejet 11001 and Twinjet J60-11003 nozzles showed that:
- the deviations from the theoretical flow values are within the permissible limits (±10%), their values being increased only in the case of using low working pressures;
- the research carried out demonstrated the fact that in laboratory conditions the uniformity of transverse distribution is characterized by a very good appreciation in the case of the nozzles taken into study; in the field, the value of the coefficient of variability can reach unacceptable values (in the case of universal nozzles), especially due to the phenomenon of drift, as a result of which it is recommended to use sprayers that provide medium droplets (even if the biological effectiveness of the respective treatment is reduced in this case);
- with the increase in pressure, the value of the degree of coverage increases (due to the increase in the degree of spraying), obtaining very fine drops; theoretically, at the same dose of applied liquid, the degree of coverage achieved by sprinkling with fine droplets (50...100 µm) is clearly higher than that achieved by using medium-sized or coarse droplets and guarantees a better biological effectiveness;
- in reality, droplets with a diameter value below 100 µm (that is, those that confer positive qualities regarding the biological effect) have a low energy, their trajectory being strongly influenced by air currents (drift, thermal effect), and their duration of existence is very short (evaporation occurring before they reach the intended target); the phenomenon of drift causes appreciable losses of pesticide substances, producing the contamination of crops or neighbouring perimeters, of

surface waters etc., thus constituting an important problem for the protection of the environment.

- for this reason, the use in practice of sprayers that provide a fine and very fine spray is more restricted because small droplets have the greatest drift potential; this aspect leads to the conclusion that simultaneously obtaining a maximum combat effectiveness and reducing to a minimum the pollution of the environment with pesticide substances are two opposite aspects of the chemical protection measures of crops.

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