RESEARCHES IN OPTIMIZING THE WORKING PROCESS OF MACHINERY USED FOR TREATMENT OF FIELD CROPS

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Abstract. Productivity in agriculture is influenced by the level of the working technologies applied, phyto-sanitary protection occupying a very important place within these technologies. Current researches and studies on the methods and equipment for applying phyto-sanitary treatments are part of the new trends for practicing sustainable agriculture, knowing that phyto-sanitary protection is one of the main sources for reducing environment pollution with chemical substances. An important aspect of the policy of each economic agent for contiguous growth of the product quality is constituted by both maintaining the conformity of machinery for plant protection, and also by increasing the premises for achieving these products in conditions of repeatability. The paper presents the experimental research conducted on a stand for a machine for applying phyto-sanitary treatments, using three types of solutions, six types of nozzles and five pressures, for each one determining the density, viscosity and superficial tension, in order to be able to determine the manner in which these properties influence the angle of the nozzle jet.

Keywords: nozzle, phyto-sanitary protection, angle.

Introduction

For a successful application of phyto-sanitary treatments to combat harmful organisms, the paths, where the active substance moves, and the ways to achieve the biological effect must be known.

An efficient application can be defined as: applying at the right moment (1), with an optimal product “density” (2), of the necessary quantity of substance (3), on the objective proposed.

The three key words are: 1 = timing (moment and frequency of the application); 2 = coverage [1] (density or number of drops); 3 = dose. Timing is the most important aspect during treatment. An application can only be efficient if it is carried out at the most favorable moment, depending on the stage of development of parasites, insects, phytopathogens, etc.

Usually, for pests the intervention should take place in the first and second larval stage. When the treatment program is well optimized, one can make considerable savings of both as the number of applications, and also as the used product. A well studied treatment program is essential for fighting and containing parasites with a reduced quantity of product and its rational use.

Coverage is the second factor for the biological result of an application. It refers to the degree of covering with drops (density or number of drops/specific surface). As the number of drops on the surface unit is higher, the efficiency will be higher. This basic principle is applied to insecticides, herbicides and fungicides [9]. Coverage is directly influenced by the angle of the spraying jet of the nozzle so that its control can guarantee a maximum coverage of the crop with the phyto-sanitary substance.

The dose. The results from experimental researches clearly show that a biological efficiency cannot be obtained unless a sufficient quantity of product is applied on the surface unit. Smaller doses of the product applied do not protect the crop enough to obtain the best efficiency, while higher doses do not show any additional advantage.

Therefore, the treatment factors (parameters) should be selected so that:

- the coverage (drop density) counted on the target surfaces should be:
  - 20…30 drops per cm^3 for herbicides;
  - 50…70 drops per cm^3 for applying insecticides;
  - 50…70 drops per cm^3 for fungicides; [3; 4]
- the volume of the norm should be adequate in order to obtain a good coverage, without causing leakages of the leaves.

The essential element in the composition of the spraying equipment is constituted by the nozzle, which has the role to allow the spraying solution to pass under pressure and to be distributed on the field [5; 6].

This paper shows the experimental determination for the evolution of the angle of the spraying jet at pressures and diameters for different nozzles using three different water solutions. This way, it was aimed to verify, if there is a correlation between the diameter of the nozzle used, the working pressure and the physical properties of the solution used concerning the evolution of the spraying jet.

Materials and methods

For conducting verifications, we chose 6 nozzles (Fig. 1) with the following characteristics: spraying angle: 120º, built from plastic material (POM of PP), with the pressure working domain of 1-6 bar. The diameter for the chosen nozzles varied from 0.1 to 0.6 mm. The nozzles were numbered L1-L6, depending on their diameter (0.1-0.6).

This type of nozzles is used for administrating phyto-sanitary substances and growth regulators and for administrating liquid fertilizers [7].

Fig. 1. **Nozzles used for experiments**

The nozzles distinguished from one another through their diameter were equipped on a special stand that simulates operation of the machine for spraying field crops, having the possibility to adjust the working pressure and rapid changing of the nozzles. This stand equipped with the manometer, two nozzle supports with 5 nozzles and the anti-dripping device, the tank and the pump with variable pressure is presented in Fig. 2.

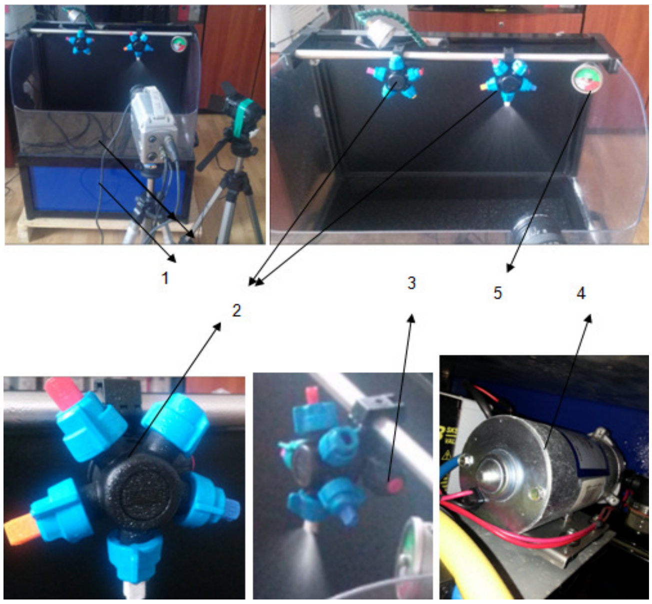

Fig. 2. **Stand for testing the nozzles:** 1 – stand for testing the nozzles; 2 – nozzle support; 3 – anti-dripping device; 4 – pump; 5 – manometer

The stand's tank was fed with three different solutions, for which the physical properties were determined: density, viscosity and superficial tension.

These properties directly influence the quality of the spraying process, each being responsible for different characteristics of it. Thus, the density influences the norm of substance per hectare depending on the temperature. Viscosity has a significant effect on the performances of the nozzles. A high viscosity of the liquid leads to a high resistance of the air where the fragmentation penetrates. The cone angle decreases along with increasing the viscosity. Viscosity also affects drop formation. The flow rate through the nozzles decreases along with the increase of viscosity.

Viscosity is responsible for the decrease of the spraying angle and for the correct shape of drops [8]. Temperature also affects viscosity, superficial tension and the specific weight of drops. A low temperature leads to an increased liquid flow rate through the nozzle.

Viscosity is the property of fluids due to which inside them tangential tensions emerge, which oppose the movement of structures in their movement towards each other. In the plane-parallel flowing regime of fluid, tangential tensions are directly proportional with the speed difference between two layers and inversely proportional with the distance between them, measured on the normal to the flowing direction. The proportionality factor that intervenes in this relation is called dynamic viscosity (η). Cinematic viscosity (v) is the ratio between dynamic viscosity and its density, at the temperature of making the determination: $v = \eta / \rho$.

Superficial tension is the general property [8] of liquids to take a geometrical shape with a minimal surface if there are no external forces, due to the action of cohesion forces inside the liquid molecules. This property makes it so that the portion of the liquid surface is attracted by another surface, such as another liquid surface. The physical quantity that characterizes superficial tension is the coefficient of superficial tension, usually denoted with the Greek letter σ (sigma), and sometimes with γ (gamma), which is an intensive physical quantity characteristic for each homogenous substance in given physical conditions.

For each nozzle measurements were conducted to determine the angle of the spraying jet for the three types of solutions used at working pressures between 1 and 5 bar. For the purpose of measuring the real angle of the spraying jet, we used a high speed recording camera, Phantom V10.0, series V 630, set to record at 80 frames per second. The software used for recording and off-line performing of the measurements was PCC-Phantom Camera Control Application [9].

Fig. 3. **Phantom V 10.0 Camera**

Thus, video recordings were carried out during operation in the stationary regime of nozzles, recording 250 frames for each type of nozzle, each working pressure and each type of solution. Five measurements were conducted for each recording, from 50 to 50 frames and then the average value of the angle of the spraying jet measured was reported for each case. Figure 4 shows the principle of conducting measuring of the angle of the spraying jet through visual identification in each frame of the generators of the cone formed by the spraying jet and prolonging them until their point of intersection. The angle α between these tangents was considered to be the angle of the spraying jet [10].

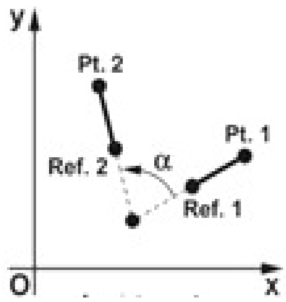

Fig. 4. **4 point representation of the angle of the jet [11]**

In Fig. 5 is presented exemplified principle of measuring the angle of the spraying jet to the left and the result of the measurements to the right.

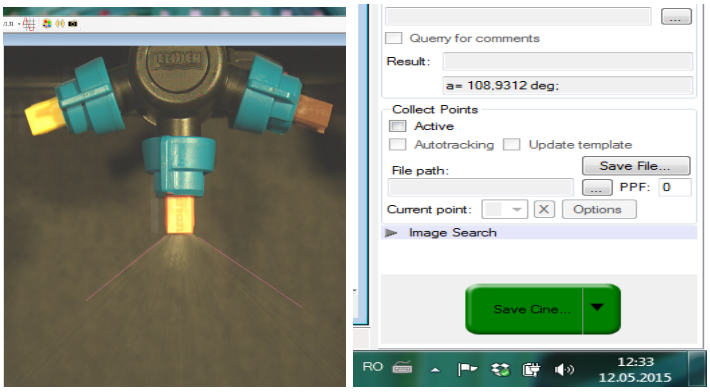

Fig. 5. **Angle of the spraying jet for the nozzle L 0.1 at a pressure of 1bar**

Results and discussion

Next, we present the particular characteristics for each water solution used, solutions that were prepared according the specification from the producers.

Solution No. 1 is a product formulated as a concentrated oily suspension (vegetable oil) that is fine, homogenous, mobile, with a tendency to set in time, but with a good capacity to reenter the system, cream colored, containing nicosulfuron 40 $g \cdot l^{-1}$, an active substance from the group of sulfonylurea herbicides.

It is a selective systemic herbicide that is absorbed through the leaves and roots, moves to the growth tissues, stopping cell division and growth of weeds, causing them to dry out. The spectrum of herbicide action includes annual monocotyledonous weeds (including species of *Setaria*, *Echinochloa*, *Digitaria*, *Panicum*, *Lolium* and *Avena*), perennial monocotyledons (*Sorghum halepense*- from rhizomes and seeds, *Agropyronrepens*), annual dicotyledonous (*Amaranthusspp* and cruciferous species). It is approved as herbicide for bristle grass (*Setaria spp*.), barnyard grass *(Echinochloa spp.),* Johnson grass from seeds (*Sorghum halepense),* and Johnson grass from rhizomes (*Sorghum halepense).*

Solution No. 1 is applied using terrestrial spraying machines, fitted with systems for contiguous stirring/homogenizing the spraying solution. Solution concentration: 0.8 %

Solution No. 2 is a systemic insecticide for combating larvae and eggs. Due to the two components, it has both systemic action and complementary physical action of asphyxiation due to the oil. It works both by penetrating the shield of larvae and eggs are intoxicated and asphyxiated so that hatching does not occur. It has lasting effect ensuring better adherence to the plant surface and a superior contact with the target pests. Different and complementary actions of the insecticide component and of the oil in the product composition prevent the emergence of the phenomenon of resistance. Solution concentration: 1.5 %

Solution No. 3 is a total, unselective, non residual herbicide, with action on a wide spectrum of mono and dicotyledonous weeds, annual and perennial, including species resistant to rhizomes. When applied post emergence, it is absorbed rapidly through the epidermis and stomata of leaves, it moves through the plant, accumulating in the meristematic tissues (growth peaks) of roots, destroying them. The effect of treatment is noticed in a 4-14 days interval, depending on local conditions. In contact with the soil, it is not persistent; it decomposes rapidly, allowing to sow the successive crop in the treated field.

Conditioning: concentrated suspension.

Characteristics: it is a total, unselective systemic herbicide. It has action both on monocotyledonous and dicotyledonous weeds, as well as on annual and perennial. It is absorbed through the leaves and moves in the entire plant, including in the underground reproduction organs of perennial plants, rhizomes or stolons. It is part of total herbicides.

Direction for use: it is applied in the phase of intense growth of weeds. It is used as drops in volume of 100-150 l of solution per hectare. It is applied at desiccant for wheat, for fighting perennial weeds hard to combat in stubbles, as well as before establishing the crops. It can be applied between the rows of vine and fruit trees at a dose of 3-4 $l \cdot ha^{-1}$.

Table 1 presents the physical properties measured for the three solutions prepared. The temperature at which the experiments were conducted was 20 ºC. The physical properties determined were relative density, viscosity and superficial tension of the water solutions used.

Table 1

Physical properties of the three water solutions used

Solution	Working temperature, ºC	Density, ρ $g \cdot cm^{-3}$	Viscosity ν, $mm^2 \cdot s^{-1}$	Superficial tension σ, $mN \cdot m^{-1}$	
				with correction	without correction
1	20	0.9965	1.44	112.43	116.89
2	20	0.9945	1.56	102.63	98.90
3	20	0.9962	1.48	96.90	101.19

As it can be noticed, even if the solutions are completely different, their physical properties taking into consideration are very close in terms of values, suggesting a minimum influence on the angle of the spraying jet.

Figure 6 shows the results of the measurements performed using solution 1.

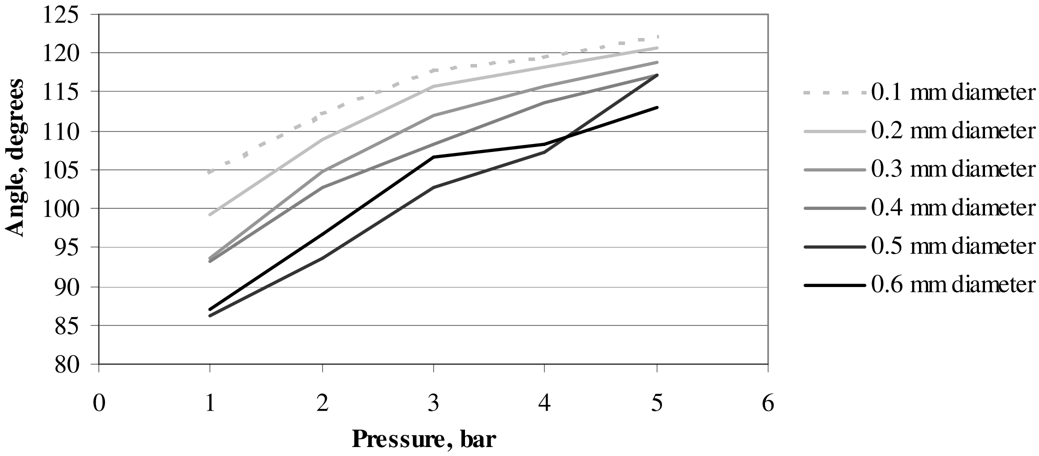

Fig. 6. **Variation of the angle of flow and pressure according to the different diameters of the nozzle for solution 1**

In Figure 7, we present the synthesis of the experiments conducted for the water solution No. 2, using the same type of nozzles in exactly the same conditions as for the other experiments conducted.

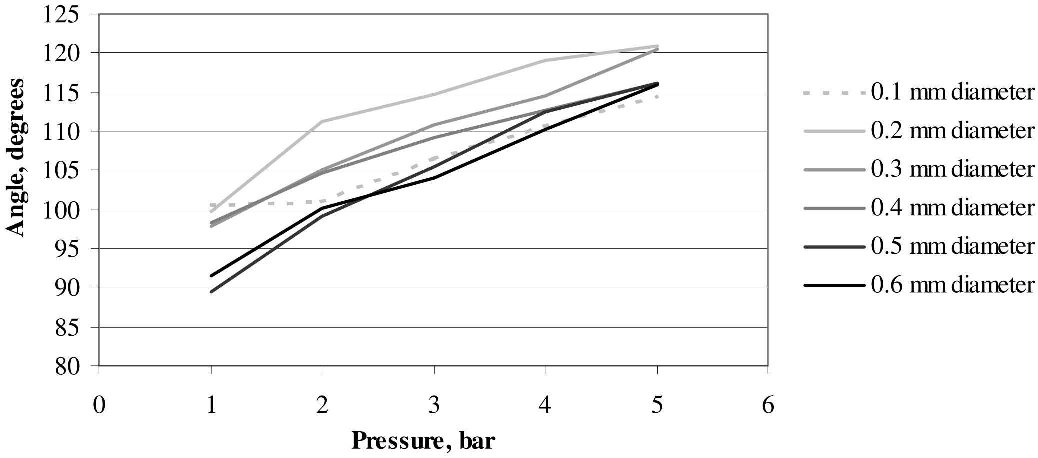

Fig. 7. **Variation of the angle of flow and pressure according to the different diameters of the nozzle for solution 2**

In Figure 8, we show the results of the experiments conducted for the water solution No. 3.

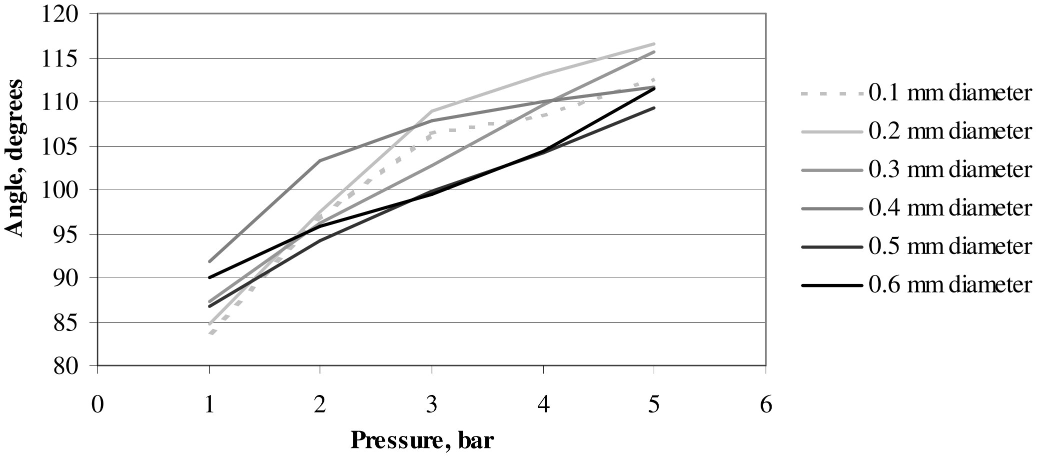

Fig. 8. **Variation of the angle of flow and pressure according to the different diameters of the nozzle for solution 3**

After processing the data shown in Figures 6-8, we summarized the average values recorded for each real case of the nozzle operation during exploitation with the three types of water solutions for the purpose of verifying from a statistical point of view the influence of the solution type on the angle of the spraying jet. For this purpose, we calculated their coefficient of variation and the standard deviation. As it can be noticed from Table 2, the values thus obtained are situated under 5 % for the majority of the nozzles used, except for the nozzles L1 and L2. For these nozzles, results above 5 % are registered for working pressures of 1 and 2 bar, pressures that are relatively low and lead to very low flow rates and to an unstable functioning of the nozzles.

Table 2

Summarizing experimental data

No.	Nozzle	Pressure, bar	Angle, degrees				Standard deviation, %	Coefficient of variation, %
			Solution 1	Solution 2	Solution 3	Average value		
1	L1	1	104.6420	100.5460	83.8920	93.2200	8.97	9.63
2	L1	2	112.1600	100.9820	96.6400	103.1065	6.54	6.34
3	L1	3	117.6800	106.4520	106.3420	110.0055	5.32	4.84
4	L1	4	119.3840	110.5900	108.3160	112.7310	4.77	4.23
5	L1	5	122.0200	114.4680	112.5240	116.8635	4.10	3.50
6	L2	1	99.1920	99.7880	84.6720	92.1755	6.99	7.58
7	L2	2	108.9300	111.1620	97.5020	106.0825	5.98	5.64
8	L2	3	115.7960	114.8160	108.9686	113.8442	3.01	2.65
9	L2	4	118.1620	119.0160	113.1340	119.5710	2.60	2.17
10	L2	5	120.7300	120.8820	116.5760	121.9860	2.00	1.64
11	L3	1	93.7220	97.8980	87.1896	91.5939	4.41	4.81
12	L3	2	104.7700	105.1700	96.1880	101.5755	4.14	4.08
13	L3	3	111.9940	110.8860	102.7700	109.0490	4.11	3.77
14	L3	4	115.6800	114.4660	109.7100	113.5590	2.58	2.27
15	L3	5	118.7880	120.4700	115.6240	118.3365	2.01	1.70
16	L4	1	93.2540	98.2980	91.8800	93.5160	2.76	2.95
17	L4	2	102.6800	104.6340	103.3280	103.2615	0.81	0.79
18	L4	3	108.1940	109.1620	107.9060	109.5430	0.54	0.49
19	L4	4	113.7500	112.6260	109.9140	113.4855	1.61	1.42
20	L4	5	117.1420	116.1000	111.6100	116.7765	2.40	2.06
21	L5	1	86.1700	89.5360	86.6420	86.6580	1.49	1.72
22	L5	2	93.5500	99.1420	94.2500	95.4435	2.49	2.61
23	L5	3	102.7760	105.4180	99.7620	103.3915	2.31	2.23

Table 2 (continued)

No.	Nozzle	Pressure, bar	Angle, degrees				Standard deviation, %	Coefficient of variation, %
			Solution 1	Solution 2	Solution 3	Average value		
24	L5	4	107.2020	112.4980	104.2360	109.4200	3.42	3.12
25	L5	5	117.1220	116.2540	109.1980	115.1370	3.55	3.08
26	L6	1	87.0580	91.5160	89.9700	89.2995	1.85	2.07
27	L6	2	96.6260	100.1220	95.7700	97.9470	1.88	1.92
28	L6	3	106.6840	103.9420	99.4600	104.5965	2.98	2.85
29	L6	4	108.2500	110.2700	104.3820	109.3925	2.44	2.23
30	L6	5	113.0480	116.0100	111.4480	115.7175	1.89	1.63

Conclusions

1. Ensuring maximum efficiency of treatments with phyto-sanitary substances in agricultural field crops is possible by building sprayers equipped with spraying systems that have superior parameters for the working process.
2. Deviations of the angle of spraying when testing on the stand and inherent even for a new nozzle have to be between limits that do not affect the repartition of fragmentation on the working width of the spraying boom, where the distributions of the nozzles overlap and the deviation of the values of overlapping does not exceed ±5 %.
3. As a result of the research conducted and after analyzing the coefficients of variation obtained for each type of the nozzles used at a certain working pressure and fed with different solutions, one can notice that the physical properties of the water solutions used do not contribute decisively to the value of the spraying jet.

Acknowledgment

The work has been funded by the Ministry of National Education and Research through the National Agency for Scientific Research, within the project entitled “Intelligent system for the active control of works for performing phyo-sanitary treatments in field crops, depending on their degree of infestation with weeds”, PN 16 24 01 05.

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