Theoretical and Experimental Research on the Technological Process of Spraying and Dynamics of the Motorized Agricultural Platform

Ph.D Student Eng. **Polifron-Alexandru CHIRIȚĂ[1],** PhD. Eng. **Corneliu CRISTESCU[1],**
PhD. Eng. **Radu RĂDOI[1],** Assoc. Prof. PhD. Eng. **Oleg CIOBANU[2]**

[1] Hydraulics and Pneumatics Research Institute INOE 2000-IHP, Bucharest, Romania; chirita.ihp@fluidas.ro

[2] Technical University of Moldova

Abstract: This article presents the results of a research developed by INOE2000 - IHP, as well as a functional model of a motorized agricultural platform used for spraying in horticulture. This is part of a complex crop monitoring system that, with the help of a quad-copter, generates a map that is used later for remote guiding of the agricultural platform, which is equipped with tracks system and a differential steering system allows it to turn in place or with a very small radius to track as accurately as possible the trajectory generated by the remote guidance system. The spraying equipment of this agricultural platform is designed to be used in a wide variety of horticultural crops with the ability to adjust both the direction and the spraying distance.

Keywords: Horticulture, remote spraying, motorized agricultural platform, hydraulic automation.

1. Introduction

Nationally and internationally, there are a variety of spraying systems of different sizes, some worn/ pushed by humans, tractor, helicopter, airplane or self-propelled. In the world, there are many companies that produce and market, including in Romania [1], such as: ROYAL BRIKMAN, global specialist in horticulture, GREGSON-CLARK, focusing on high-quality sprinkler equipment in green industry, EMPAS, in horticulture spraying equipment, HYDRO SYSTEMS EUROPE with irrigation and horticultural applications, MARTIN LISHMAN Ltd and others [2,3,4]. Some of the machines produced by these companies are shown in Figure 1.

Fig. 1. Examples of spraying equipment available worldwide.

In the market of Romania, except those carried by humans, there are conventional sprayers. Generally large spraying sizes for large crops with high productivity, not fully satisfying market requirements, requiring medium-sized self-propelled machines that need small-scale SMEs in horticulture. Sprayed crops are sprayed using systems worn or towed by humans. In Romania

there is no spraying technology and no specialized equipment. Recognizing this market failure, the beneficiary SME is requesting funding for this project, which will launch an innovative product based on new, productive and competitive technology, useful and necessary in horticulture in Romania.

The necessity and usefulness of spraying equipment is given by the modernization of the technologies for the realization of the horticultural works, but especially by the introduction of innovative equipment, ensuring both high productivity and quality food production, knowing that on the market, is an increasing demand for clean organic / ecological products to ensure healthy food for the population. One of the agricultural activities, which is quite frequent in the horticultural sectors, is the spraying of crops, both for outdoor purposes, but especially for crops growing in sheltered areas such as solariums, greenhouses, etc. At world level, there are particular concerns and achievements with regard to crop spraying equipment in the horticultural sectors. These equipment are very diverse in terms of how they are transported / brought to the place where the spraying is to be performed. These can be: manned equipment; equipment worn on tractors; trailed spraying equipment and self-levelling equipment. Worldwide there are airplane-mounted spraying equipment, helicopters even drone, which reacts the automatic sprinkling of crops located on designated stations.

2. Theoretical aspects of the spraying process

The nozzle spraying process is characterized, first of all, by the particle velocity and the spraying distance, under a certain working pressure and a given nozzle diameter.

For the mathematical modelling of the nozzle spraying process, a nozzle of diameter d, fed through a pipe of diameter D, with a flow Q, from a pump P, to the pressure p, controlled by means of a limiting valve SLP pressure. The nozzle of length h is horizontally stacked and spans, over a certain distance, on a trajectory considered to be a semi-parabola.

Figure 2 shows the physical modelling of the spraying process with specific main parameters, as well as the parabolic trajectory the water drops through.
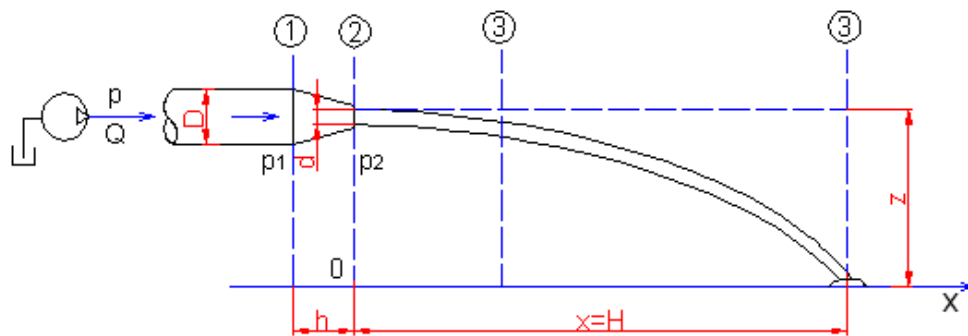

Fig. 2. Particle trajectory at spray nozzle

For the mathematical modelling of the spraying process, the BERNOULLI [5] equation used in points 1 and 2 above leads to equality (1):

$$z_1 \; \frac{p_1}{\gamma} + \frac{V_1^2}{2g} = z_2 + \frac{p_2}{\gamma} + \frac{V_2^2}{2g} \tag{1}$$

Since the nozzle is horizontal, $z_1=z_2$ and the exit nozzle pressure is $p_2=p_a$, where p_a is the atmospheric pressure which is equal to 0 bar as real pressure. The relationship (2) is obtained:

$$\frac{p_1}{\gamma} + \frac{V_1^2}{2g} = 0 + \frac{V_2^2}{2g}, \tag{2}$$

Which allows the liquid velocity v_2 to be calculated at the outlet of the nozzle, with the relation (3):

$$V_2 = \sqrt{\frac{2}{\rho} \cdot p_1 + V_1^2} \tag{3}$$

To determine the maximum sprinkling distance, consider the equation of the classical parabola (4):

$$y = az^2 + bz + c \tag{4}$$

The shape of the liquid particle trajectory is represented by the positive part of the graph in Fig. 3.
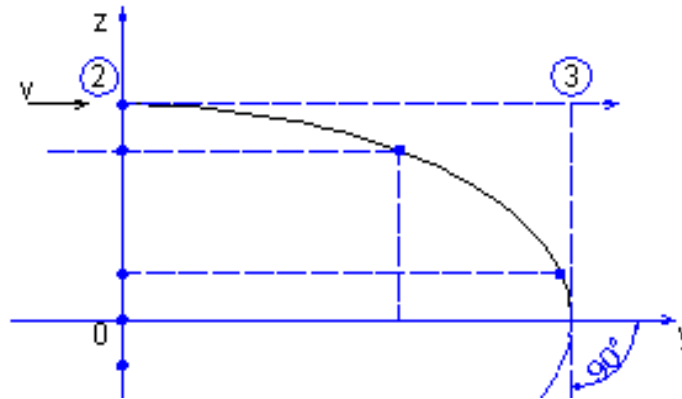

Fig. 3. The trajectory travelled by the liquid particle

It is believed that the nozzle is at a height sufficient for the particle to lose all the energy from the pressure even when it reaches the surface of the ground, and from this point the particle will fall vertically with the gravitational acceleration g. that the parabola is symmetrical with respect to the y-axis and the boundary conditions at points 2, where the velocity of the liquid particle is the velocity v_2 determined above, and in point 3 is null, the equation of the parabola of the form (5):

$$y = -\frac{g}{2} \cdot z^2 + y_{max} \tag{5}$$

Based on this equation, it is possible to determine the particle velocity of the liquid at each point of the trajectory and the maximum spraying distance, taking into account the actual nozzle height of the nozzle from the point 2 to point 0. The above, along with pipeline flows, are used to develop the numerical simulation model of the spraying process.

3. Numerical simulation of the spraying process

On the basis of the elaborated mathematical model, coupled with aspects of pipe pressure losses, a complex model [6] has been developed which has allowed a numerical simulation of the spraying system shown in Figure 4.
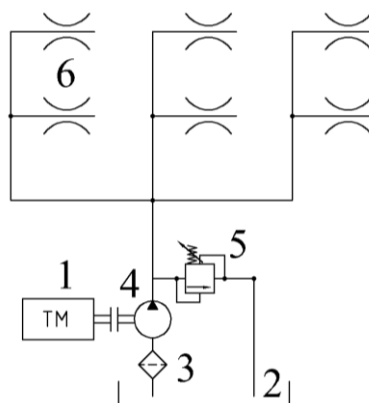

Fig. 4. Hydraulic scheme underlying the numerical simulation model
1 - thermal engine, 2 - tank, 3 - filter, 4 - hydraulic pump, 5 - pressure valve and 6 - spray nozzles.

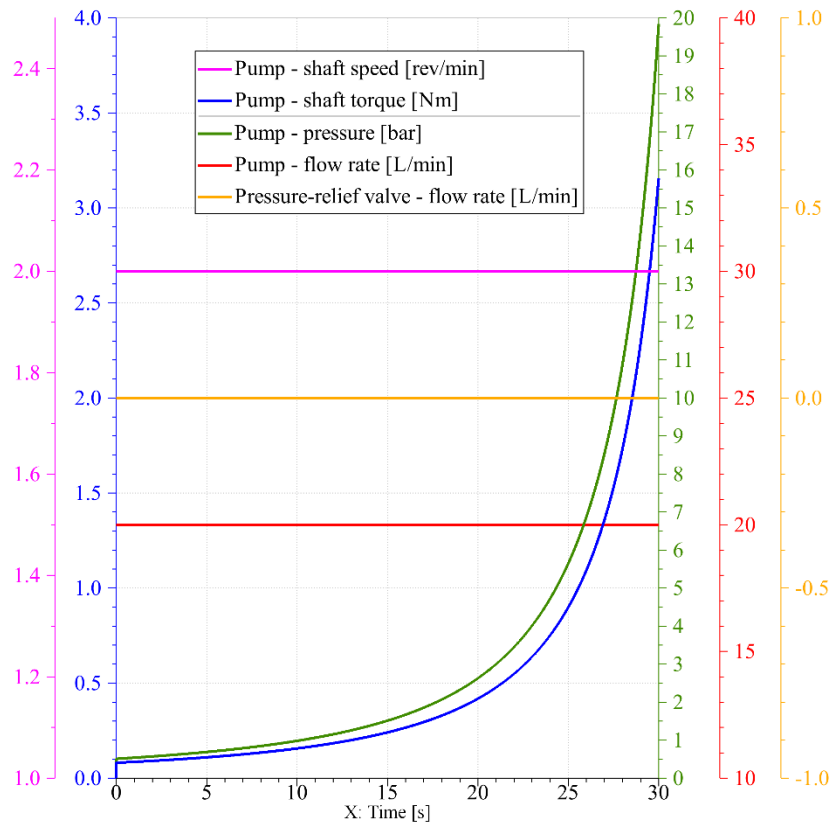Parameters of simulation and its results are presented in the graphs in the figures below.

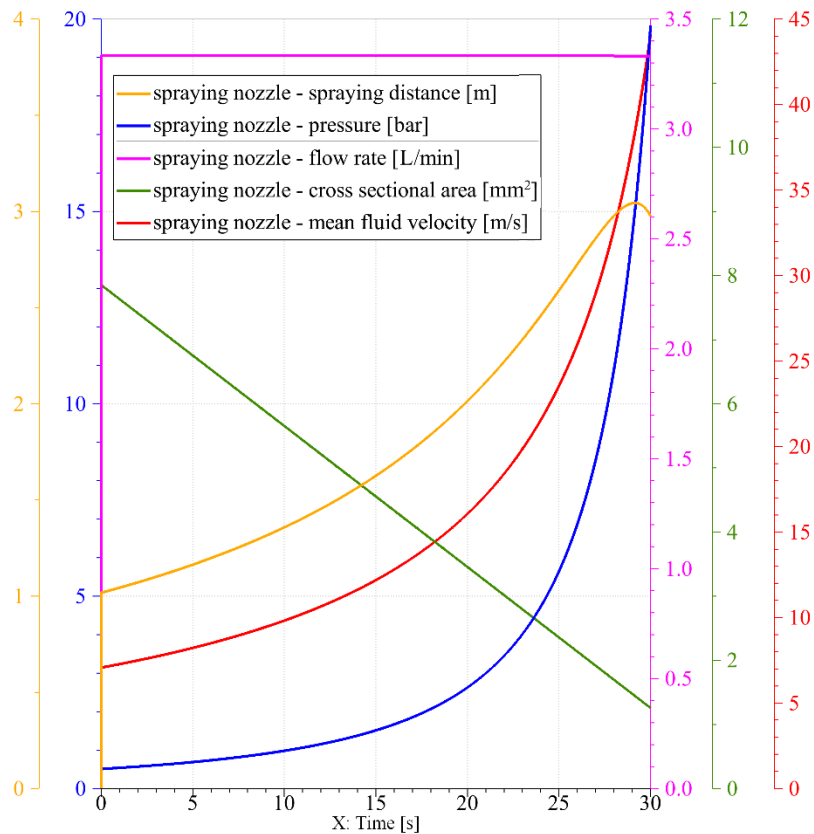**Fig. 5.** Pump and pressure valve parameters.

Fig. 6. Results of numerical simulation of nozzle parameters

This numerical simulation model allows optimization of the spraying process by choosing the nozzle dimensions correctly depending on the required performance. Figures 5 and 6 show the main parameters of the simulation, of interest being the variation in time of the spraying distance, which changes with the nozzle section variation.

The spraying distance can also be changed by adjusting the pressure by means of the pressure valve, but this adjustment is energy disadvantage because part of the flow will be transmitted to the tank passing through the pressure valve, resulting in a low energy efficiency.

In these graphs it can be seen that the constant parameters are: pump speed, pump flow rate, nozzle flow rate and flow through the pressure valve. The rest of the parameters vary over time because the diameter of the nozzle's changes from a maximum value to a minimum, which causes the values of the following parameters to increase: working pressure, fluid velocity, and last but not least the spraying distance ranging from 1 to 3 m. If the nozzle section decreases after a linear law, it can be noticed that the pressure increases exponentially and from a certain value of the nozzle section, the spraying distance is limited to a quasi-constant value. Lowering the section below this value should be avoided, as energy consumption increases substantially resulting in high energy consumption.

4. Brief presentation of the motorized agricultural platform

The conceptual model proposed for the motorized spraying platform is shown in Figure 7 below.
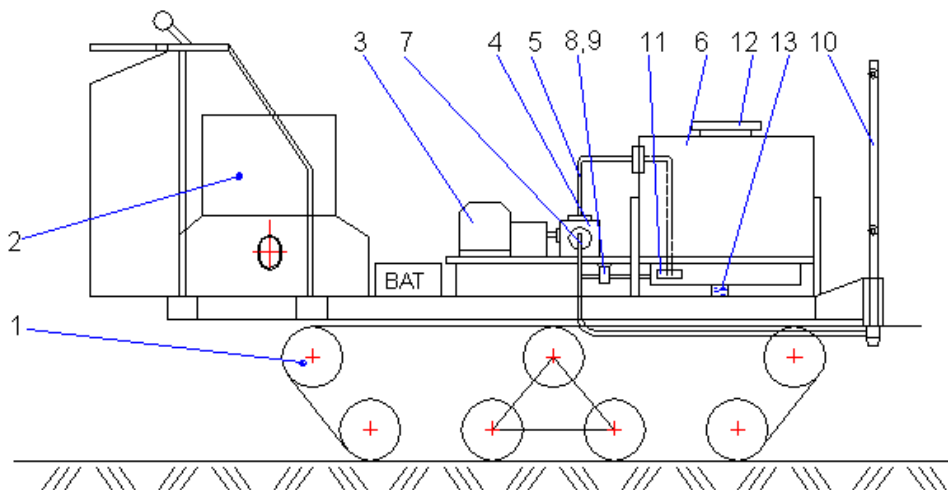

Fig. 7. Agricultural spraying platform

The conceptual model was conceived as a technical solution for long-distance spatial spraying, specific to crops and vines. The pattern is, in part, similar to the one above. It is also composed of a self-propelled platform on tracks (1), equipped with a thermal motor (2), which includes the fuel tank, the electric battery and a hydrostatic actuator, the thermal motor (3), the drive motor (4), the suction line (5), the liquid reservoir (6), the pressure relief pipe (7), the pressure limiting valve (8) and the return line (9) (10) whereby two spraying modes can be selected: spraying small plants when the dispenser arms are in the horizontal position or lateral spraying when the arms of the device are in the upright position. The machine is also provided at the end of the suction pipe with a corresponding filter (11), a visor cover (12) to the tank (6) and, of course, a drain plug (13) to the tank. As far as platform control is concerned, it is carried out manually as well as via distributors, and the levers can also be operated by means of servo-controls, which allow interfacing with the remote control / guidance system, which respond to the orders given by remote operator via a command console.

For the elaboration of the execution documentation, a 3D model was developed, as shown in Figure 8.

Fig. 8. The 3D model of the agricultural platform

The motorized agricultural platform has the possibility of spraying both the plants at the ground level as well as the trees or the vine, these can be achieved by placing the two spray arms vertically or horizontally, as shown in Figure 9.

Fig. 9. Physical realization of the agricultural platform

Technical characteristics and performance parameters of the agricultural platform:

- type of spraying: a) lateral, with vertical arms and b) horizontal;
- spraying distance .... max. 3 m;
- spray rate .... max.20 l / min;
- spraying pressure .... max. 20 bar;
- power of the spraying engine .... 1 kW;
- spraying capability .... 100 l;
- displacement motor power .... 5.2 kW / 1800 rpm;
- travel speed .... 0 - 7 km / h:

5. Experimenting and functional testing of the product

After the complete assembly of the experimental model of spraying platform was carried out, a series of house samples were carried out, in INOE 2000-IHP, samples which were designed to

carry out the displacement and operation commands, according to the technical documentation, as such as gear shifts and change of travel direction. These are shown in Figure 10.

Fig. 10. Experimentation at the institute

Following these homemade samples, the experimental model of the motorized agricultural platform was declared complete, suitable for functional testing under real working conditions. In order to perform functional testing in real working conditions (shown in Figure 12), the product has to be transported to a field with a suitable culture.
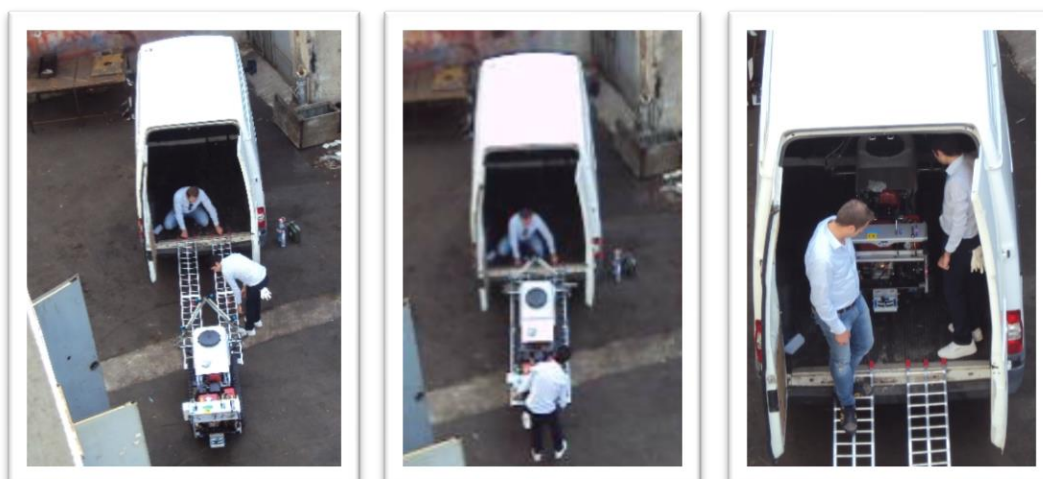

Fig. 11. Images from loading the product for transportation

Fig. 12. Functional testing in real working conditions

Functional testing of the experimental model of a spraying motorized agricultural platform was done under real working conditions on a land with a corresponding horticultural crop. Functional testing was done according to a procedure (scenario) established in the institute, in order to determine, experimentally, basic kinematic parameters and technological parameters.

The parameters to be determined are of two categories.
I. Kinematic (motion) parameters on 3 gears:
- the displacement speed, determined by integration of the acceleration;
- acceleration of the displacement, measured with the accelerometer;
- the distance travelled, determined by the integration of the speed and measured with the roulette.
II. Spraying technology parameters:
- workflow, measured with a flow-meter inserted on the tropics pump circuit.
- working pressure, adjusted to the valve and measured with an existing manometer;
- spraying distance, measured with roulette,
The following results were obtained after the functional test under the working conditions.
Measured kinematic parameters. When measuring the acceleration of movement with accelerometer and signal processing by simple integration for double speed and displacement was obtained graph in Figure 13.
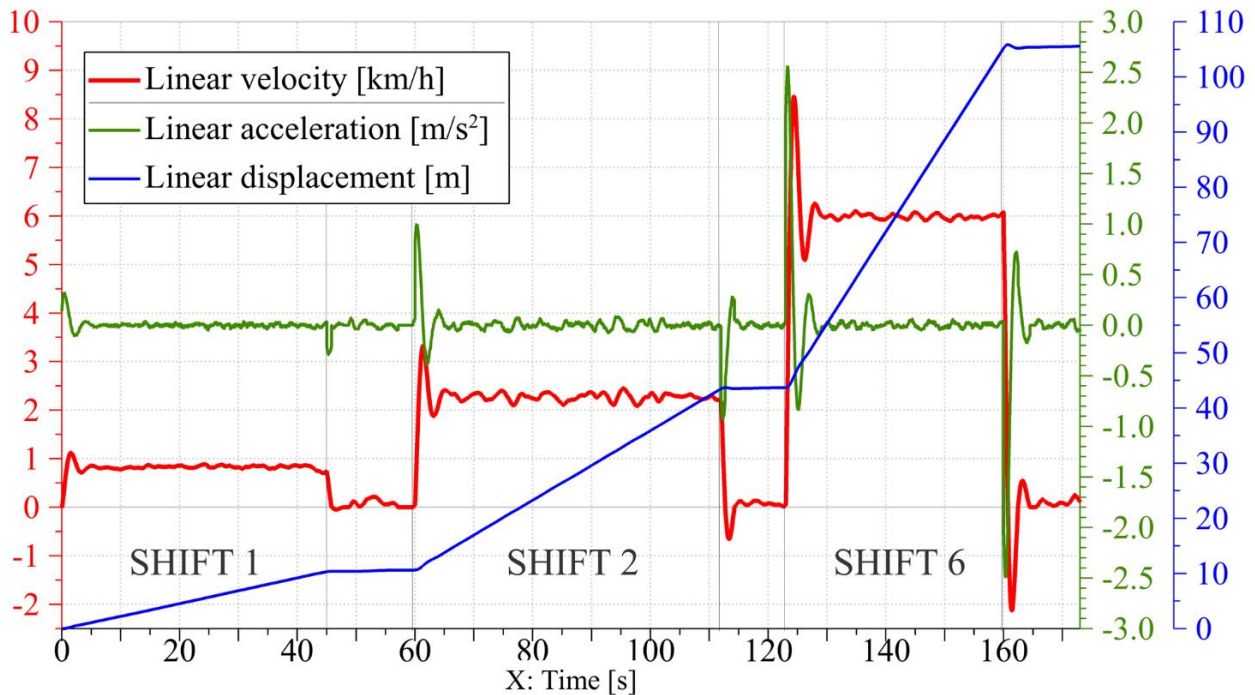

Fig. 13. Kinematic parameters

Table 1 below shows the measured spraying distances, as compared to numerical simulation, with the percentage differences being explicable and acceptable.

Table 1: Spraying technology parameters

Pressure [bar]	Flow [l/min]	Spraying distance [m]		Difference percentages [%]
		Numerical simulation	Measured	
5	20	1.0	0.8	25
10	20	2.0	1.8	11
20	20	Max. 3.2	3.0	7

6. Conclusions

Following the research project funded by the Innovation Checks Program, it can be concluded that this program is a generating program of progress, because these projects result in performing products with a high chance of being capitalized in the market economy.

Following technical documentation in the country and worldwide, on the achievements of machinery and equipment for spraying and / or spraying plants in the horticultural sector, the following conclusions were reached:

- Worldwide, modern wetting, spraying, spraying technologies have been developed to maintain, treat crops specific to the horticultural sector;

- In the world, a lot of types and sizes of spraying and spraying machines have developed;

- Such achievements are in the country, but in less diversity, but some are sold out;

- Following the documentation, two conceptual models were proposed, one with pneumatic spraying and one with hydraulic spraying, both mounted on track platforms.

- The experimental model of the motorized agricultural platform has both manual and remote controls and has undergone functional testing, both in the institute and in real field conditions, the technological results obtained being in full conformity with the technical documentation elaborated;

- The project was fully realized, all the activities and deliverables of the project being carried out in accordance with the project offer, all the status and progress indicators being achieved.

The project will be capitalized, following intensive marketing by the beneficiary SME, by developing a technical documentation for a prototype, in line with the concrete requirements of an interested customer in the market and then by introducing it into the manufacturing.
Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

Acknowledgments

References

[1] Dejeu, L., C. Petrescu, and A. Chira. *Horticultură şi protecţia mediului*. Bucureşti, Edit. Didactică şi Pedagogică R. A., 1997.
[2] Brumă, Ioan - Sebastian. *Tehnologii ecologice de întretinere a pomilor fructiferi*. Iași, Edit. Terra Nostra, 2004.
[3] Bălan, Viorica, L. Dejeu, A. Chira, and Ruxandra Ciofu. *Horticultura alternativă şi calitatea vieţii*. Bucureşti, Edit. G.N.P. Minischool, 2003.
[4] ***. "Tehnologii performante pentru tratamentele fitosanitare în vii și livezi." *Agro Business* (6 mai 2015). In: https://www.agro-business.ro/tehnologii-performante-pentru-tratamentele-fitosanitare-in-vii-si-livezi/2015/05/.
[5] Mecanica Fluidelor. Formule. In: http://www.e-formule.ro/wp-content/uploads/mecanica%20fluidelor.pdf.
[6] Anton, Viorica, Mircea Popoviciu, and Ioan Fitero. *Hidraulică şi Maşini hidraulice*. Bucureşti, Editura Didactică şi Pedagogică, 1978.