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INSTITUTE OF SOIL SCIENCE, AGROTECHNOLOGIES AND PLANT PROTECTION "NIKOLA PUSHKAROV"

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INVESTIGATION OF ROTARY SPRAYERS FOR BOOM SPRAYERS

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of Ph.D. THESIS

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RELEVANCE OF THE TOPIC

The European Parliament and the Council of Europe have recognized in the Decision adopting the Sixth Community Environment Action Program that the adverse effects of pesticides on human health and the environment need to be further reduced.

On the other hand, the world's population is constantly growing, with an increase of 80 million per year over the last 50 years. In order to provide food for the world's population, it is necessary to increase food production at the same rate. Under these conditions, it is unrealistic to expect food production without the use of pesticides in the near future.

Modern pesticides are becoming more effective and this requires application that is much more precise.

Two types of sprayers are used for plant protection - fan and boom. Bar sprayers are the most widespread. They have hydraulic-personal sprinklers that generate drops of different sizes. All this requires improvement of the spraying systems of the boom sprayers.

SCIENTIFIC INNOVATION

A methodology for determining the optimal location of rotary sprinklers on the frame of a boom sprayer has been developed. Software for machine calculation of the parameters of the distribution along the length of the bar has been substantiated and developed. New hydraulically driven rotary spreaders and test stands have been developed. Existing sprinklers have been modified and their parameters have been studied and analyzed.

PRACTICAL USEFULNESS

In the present study, technical solutions of sprayers for boom sprayers are studied and proposed and their parameters and modes of operation for realization of the desired drip coating are substantiated, thus creating preconditions for reducing the costs of performing plant protection work and of environmental pollution and agricultural production.

OBJECT OF THE RESEARCH

The object of the study are several types of rotary sprinklers. Four modifications of rotary sprayers of our own design and original rotary sprayer Micromax III of the English company Micron Sprayers Ltd and a modified by us such sprayer, in different positions relative to the sprayed surface, were studied.

SUBJECT OF THE RESEARCH

The subject of the research are the parameters and modes of operation of rotary sprayers to a boom sprayer

Chapter 1. PROBLEM STATUS

There are different classifications of methods for conducting plant protection activities. Our plant protection science adopts the following main classifications: agrotechnical, physical, biological, chemical and combined methods.

CLASSIFICATION OF SPRAYERS

Sprayers can be classified according to different characteristics (Fig. 1.1.)

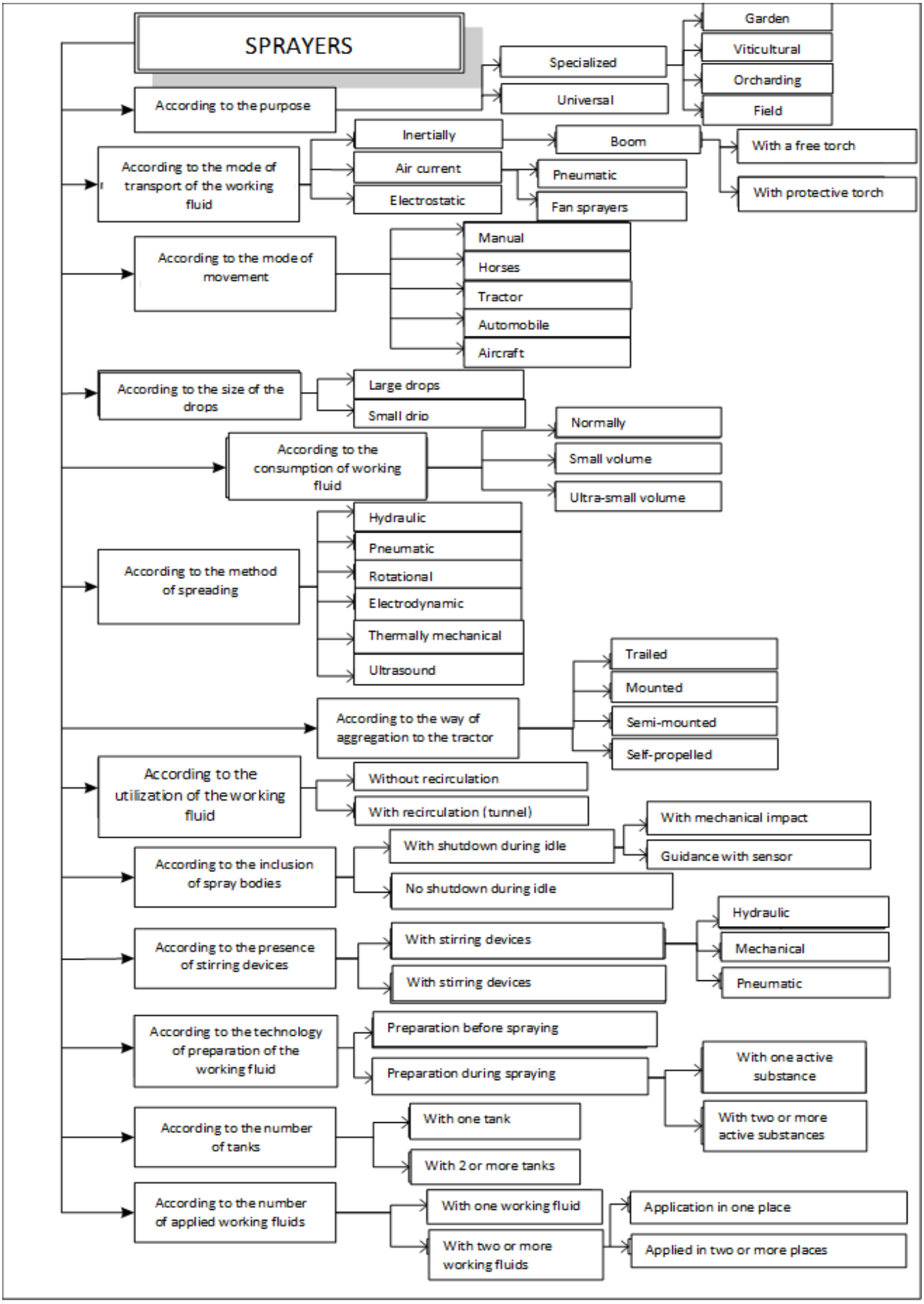


Fig. 1.1. Classification of the sprayers

In addition to the distribution of the working fluid over the width of the torch, the size of the droplets and their density are also elements of the quality of work of the machine. They are important for the uniform coverage of the treated object.

Chapter 2. PURPOSE, TASKS AND METHODOLOGY OF RESEARCH PURPOSE

Justification of the parameters and modes of operation of rotary sprayers to the boom sprayer to ensure even distribution of the working fluid.

TASKS

1. Theoretical development of the spraying process in rotary spreaders.
2. Justification of the controllable factors and parameters characterizing the mode of operation of rotary sprinklers.
3. Development of methods programs and stands for conducting experimental research on the process of spraying the working fluid.
4. Justification of the optimal mode of operation and location of sprayers to the boom sprayer depending on the type of sprayer, in order to obtain an even distribution of the working fluid.
5. To substantiate the technology and technical means for work on the technology for controlled drip coating.

ROTARY SPRINKLER DEVELOPED BY US

A rotary sprinkler has been developed in the ISSAPP ”N. Poushkarov” (Fig. 2.1.).

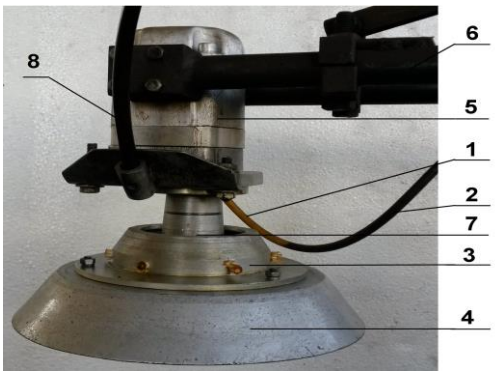


Fig. 2.1. Rotary sprinkler developed in ISSAPP "N. Poushkarov"

1. Pipeline; 2. Hydraulic fluid 3. Housing 4. Spraying working body 5. Hydraulic motor; 6. Frame (Hydraulic fluid lines; 7. Hydraulic motor shaft; 8. Working fluid line

ROTARY SPRAYER MICROMAX III

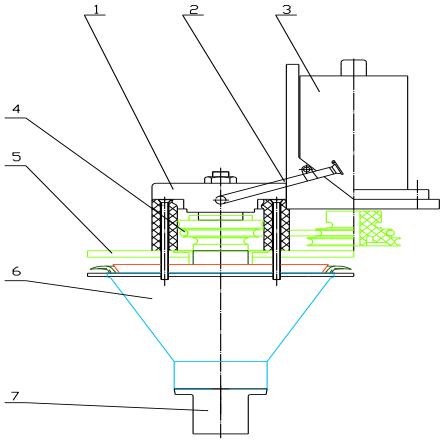


Fig. 2.2. Micron rotary spreader diagram

1. Carrier; 2. Lubrication device; 3. Electric motor; 4. Belt gear; 5. Plank; 6. Sprinkler; 7. Cap

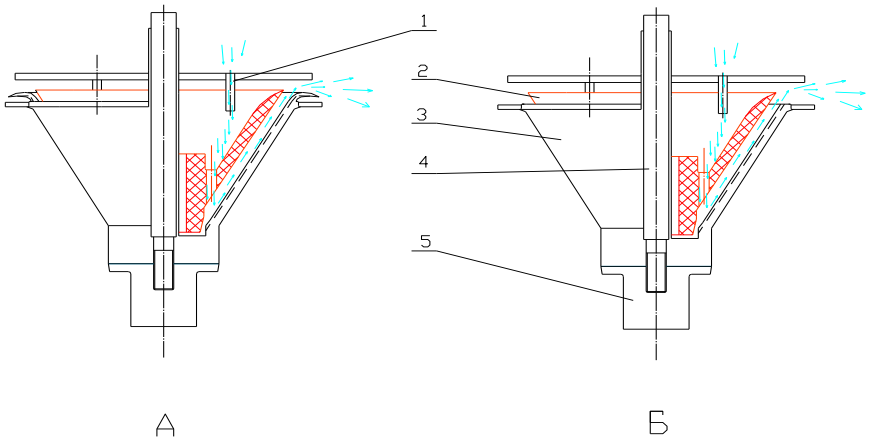


Fig. 2.5. Spraying technology for Micromax III – A, modified version - B.
1. Dispenser 2. Fixed conical cup 3. Rotary spray body 4. Drive shaft 5. Cap

METHODOLOGY FOR INVESTIGATION OF SPRAYERS

The three modifications of the developed rotary sprayers are hydraulically driven. They were tested by being driven by a hydraulic station connected according to the scheme shown in fig. 2.3. From the scheme of the experimental system, it can be seen that there are two sprinklers mounted by two hydraulic motors. The two hydraulic motors are connected in series, which implies that they have the same speed. The hydraulic station supplies pressurized oil, the flow of which is regulated by the flow regulator (7) and thus the speed of the sprinklers can be regulated in a very wide range. The two sprinklers are connected in series, which implies the same speed. The speed of the sprinklers is measured on one of them with a tachometer. No working fluid is supplied to this nozzle on which the speed is measured. By means of a tap and measuring with a flow meter, the desired flow rate is fed to the sprinkler to be tested.

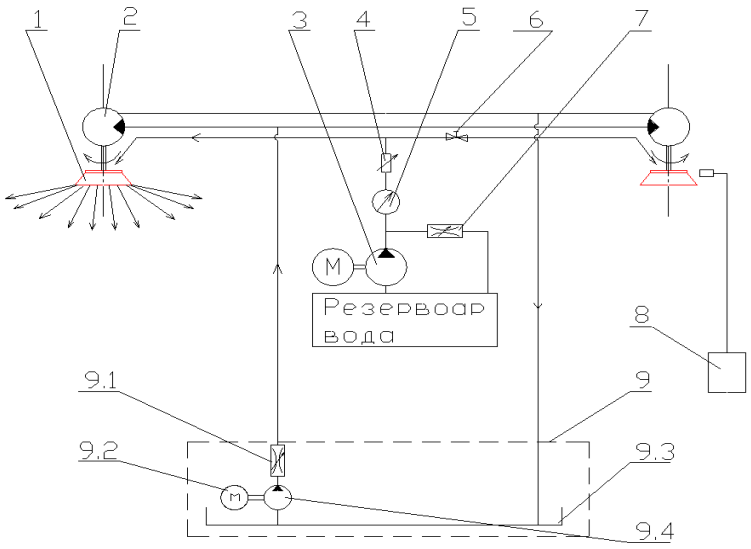


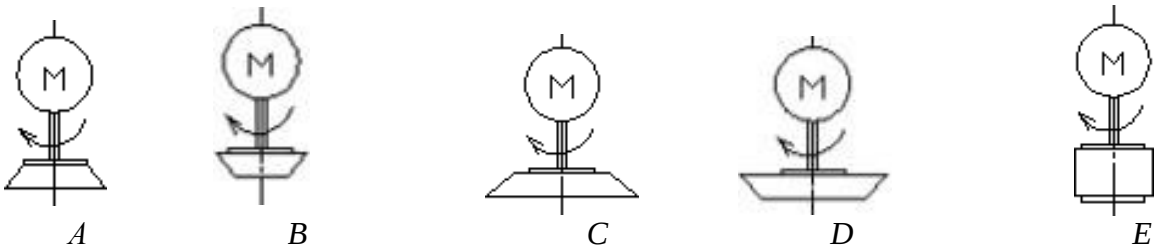
Fig. 2.3. Schematic diagram of the experimental system

1. Sprinkler; 2. Hydraulic motor; 3. Water pump; 4. Flow meter; 5. Manometer; 6. Stopcock; 7. Flow regulator; 8. Measuring device; 9. Drive hydrostation; 9.1. Flow regulator; 9.2. El. engine; 9.3. Hydraulic oil tank; 9.4. Hydraulic pump.

The frequency of rotation of the rotary sprinklers was determined under the premise of providing the same peripheral speed of the different tested sprinklers. This ensures comparability of the results obtained depending only on the shape and size of the sprayer.

In Fig. 2.4. the layout diagrams of the developed rotary spreaders are shown. It is possible to mount them to the hub in two positions on the spreading surface - down (as in Fig.2.4 A, C) and

up Fig. 2.4 B, D. Variants B and D have two versions - with smooth and serrated periphery (Fig. 2.5. A, B)



A *B* *C* *D* *E*

Fig. 2.4. Schemes of the studied variants rotary sprinklers own design
A - diameter 254 mm turned down, B - diameter 254 mm turned up, C - diameter 330 mm turned down, D - diameter 33 0mm turned up, E - type mesh.



A) With a smooth periphery *B) With jagged periphery* *C) Dram*

Fig. 2.5. Types of spreading working bodies

The investigated sprinklers are placed in a different position relative to the sprayed surface. The flow rates are selected in the operating range of the sprinkler. Their measurement and maintenance was performed with AAMS Passive Flow Meter Sprayers [Salvarani srl]. With the sprinkler facing downwards, experiments were performed at a height of H=50 cm, flow rate D=2.8 l/min and the speed was changed n = 1500, 1600, 2100, 2200, 2650, 2800 min^{-1}.

With the nozzle facing upwards, experiments were performed at the nozzle height H = 50 cm, flow rate D=2.8, 1.8, 0.8 l/min. At D=2.8 l/min the rotational speeds n=1120, 1300, 1540, 1740, 1960 min^{-1} are changed. At D=1.8 l/min the speed n=1120, 1540, 1960 min^{-1} is changed. At D=0.8 l/min the speed n=1120, 1540, 1960 min^{-1} is changed.

METHOD FOR INVESTIGATION OF MICROMAX III SPRAYERS AND MODIFIED VERSION

The distribution of the working fluid along the working width of the sprayer for three speeds of rotation and three flow rates of working fluid was studied. Two variants of the dispersion body location were studied - turned up and down, located 0.5 m above the catching surface. The distribution of the working fluid on the working fluid of the sprayer width for the three operating modes of the Micromax III sprayers (2000, 3500, 5000 min^{-1}) at different flow rates and three different heights (H=30; 40; 50 cm) of the sprayers located above the collecting tray. The three operating modes realize a peripheral disk speed of 6.5 respectively; 11.4 and 16.2 m/s. The yellow nozzle from the kit to the sprinkler is used. The flow rates are selected in the upper operating range of the sprayer and are operated with flow rates of 1.2; 1.5; 1.8; 2.1 and 2.4 l/min. Their measurement and maintenance was performed with a flow meter AAMS Passive Flow Meter Sprayers.

INVESTIGATION OF THE DISTRIBUTION OF THE WORKING LIQUID ACCORDING TO THE WORKING WIDTH OF THE SPRAYER

The study of the distribution of the working fluid along the working width of the sprayer is performed with the help of a stand made for this purpose, the general appearance of which is shown in Fig.2.6. It is a gutter tray with the dimensions and depth of the gutters 100 mm shown in Fig. 2.7. It is made according to the requirements of ISO 5682- 1/1996.



Fig. 2.6. General view of the gutter tray

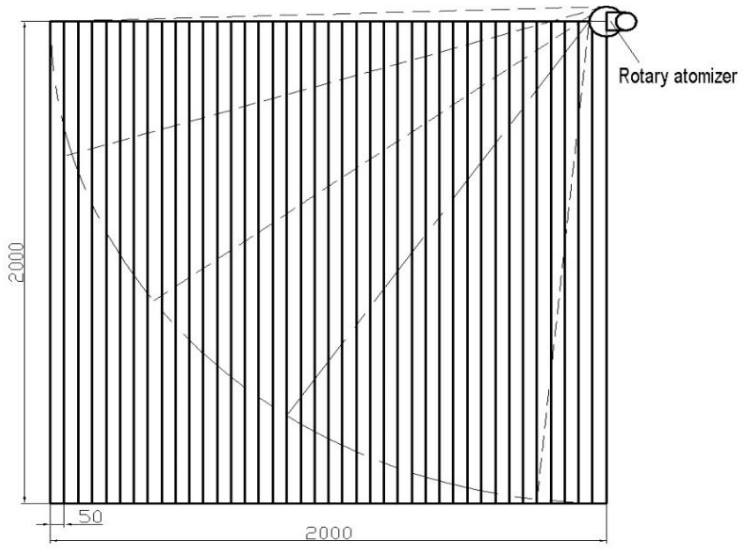


Fig. 2.7. Diagram of the sector from which the working fluid is collected

Chapter 3. THEORETICAL INVESTIGATIONS OF THE SPRAYING PROCESS DURING THE OPERATION OF A ROTARY SPRAYER FROM A BAR SPRAYER

DROP FORMATION IN ROTARY SPRAYERS

Of the known spraying methods, the rotary one has the richest possibilities for providing drops with the desired diameter. Spraying liquid with rotary sprinklers is a complex physical process that depends on many external and internal factors that determine the diameter of the resulting droplets.



a) *b)*

Fig. 3.1. General type of drip formation in a) the sprinkler is our development b) for Micromax III



Fig. 3.2. General appearance of the torch when working with a drum sprayer

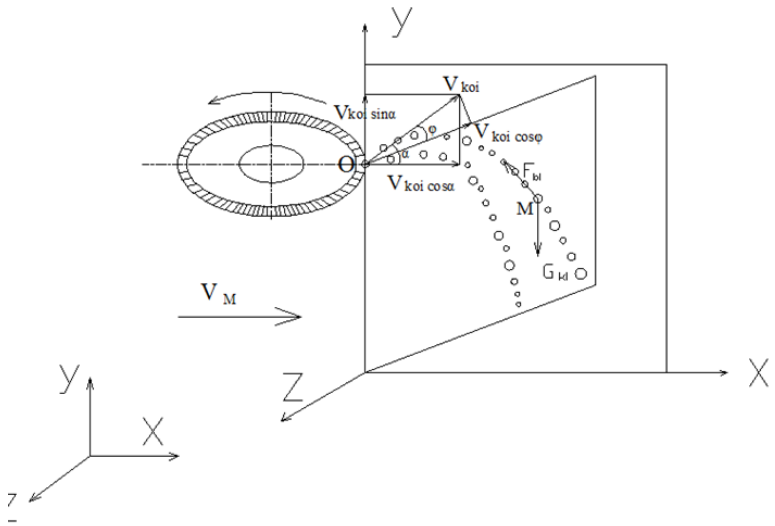


Fig. 3.3. Graphical representation of the accepted notations of the parameters during the movement of the droplets after spraying.

The absolute speed is directed at an angle α, the angle of inclination of the spray surface of the spreader. Its size is determined by the formula:

$$V_{K0i} = \sqrt{V_{k0ix}^2 + V_{k0iy}^2}, \qquad (3.1)$$

where: V_{k0ix} and V_{k0ix} are the projections of the absolute velocity of the droplet leaving

the peripheral surface of the diffuser, respectively, along the X and Y axes of the absolute coordinate system.

In turn, these components are defined by the expressions:

$$V_{k0ix} = V_{3x} - V_M\ , \quad V_{k0iy} = V_{3y}, \tag{3.2}$$

where: V_{3X}, V_{3Y} are the projections of the velocity of the diffuser cup of the diffuser along the X and Y axes of the relative coordinate system, respectively.

Projections V_{3X} and V_{3Y} depend on the angle α and are determined by the following formulas:

$$V_{3X} = V_3 \cos\alpha\ ; \qquad V_{3Y} = V_3 \sin\alpha\ . \tag{3.3}$$

By substituting formulas (3.2) and (3.3) in formula (3.1), the final expression (3.4) is obtained for finding the absolute velocity of the droplet leaving the sprinkler and passing to the treated objects.

$$V_{K0i} = \sqrt{(V_3^2 cos\alpha - V_M)^2 + (V_3\ sin\alpha)^2} \tag{3.4}$$

This is the case when the direction of flight of the drop is in the longitudinal vertical plane relative to the direction of movement of the machine. There are two ways to find the general case. One is by considering a spatial coordinate system and in addition to the x and y axes, the z coordinate is introduced, or in formula 3.4. instead of V_M, we introduce a function f (V_M) formula (3.5) which is a periodic function varying in the range from zero to V_M. V_M=0 in the case where the flight speed is perpendicular to the direction of travel. Then the projection of the translational velocity of the machine V_M in the considered plane is equal to zero. The other limit case is when it accepts a V_M value the case described by formula 3.4.

$$V_M = f(V_M) \tag{3.5}$$

All these phenomena show that a deformation of the torch occurs due to the translational speed of the machine (Fig. 3.4).

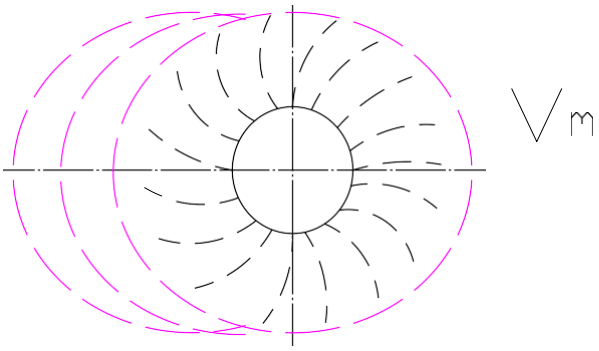


Fig. 3.4. Influence of the translational speed on the deformation of the spreading torch

In order to study this deformation of the spreading torch, a rectangular coordinate system in the longitudinal horizontal plane with respect to the direction of movement of the machine is considered, so the influence of the translational speed is most clearly seen. A case of placement of the spray disk in the considered plane is considered. Variants of position in the longitudinal vertical plane are possible when spraying high-stemmed crops such as sunflowers or fruit crops and vines, then the deformation of the torch should be similar but rotated 90 ° after it is further proven that the impact the force of gravity or the mass of the droplets do not affect the trajectory of movement. Seen from above,

in this case there is a bending of the spreading torch. To some extent, this shortcoming is overcome by fan sprayers, where the speed of the spray jet is much higher than the speed of the machine, but even with them this phenomenon cannot be ignored. Similar to formula 3.4, the initial velocity in the xOz plane is:

$$V_{K0i} = \sqrt{(V_3^2 cos\varphi - V_M)^2 + (V_3\ sin\varphi)^2}, \qquad (3.6)$$

where φ is the angle of rotation of the spray cup.

The choice of diameter of the used drops must be in accordance with their possibilities for removal (Fig. 3.5) and their evaporation (Fig. 3.6). The graph shows that in these conditions drops with a diameter of more than 0.180 mm apply to 2 m. The rate of evaporation has a linear correlation with the diameter of the droplets, the larger their diameter the higher the rate of evaporation. It should be borne in mind that as a result of evaporation, the concentration of the active substance in the drop also changes.

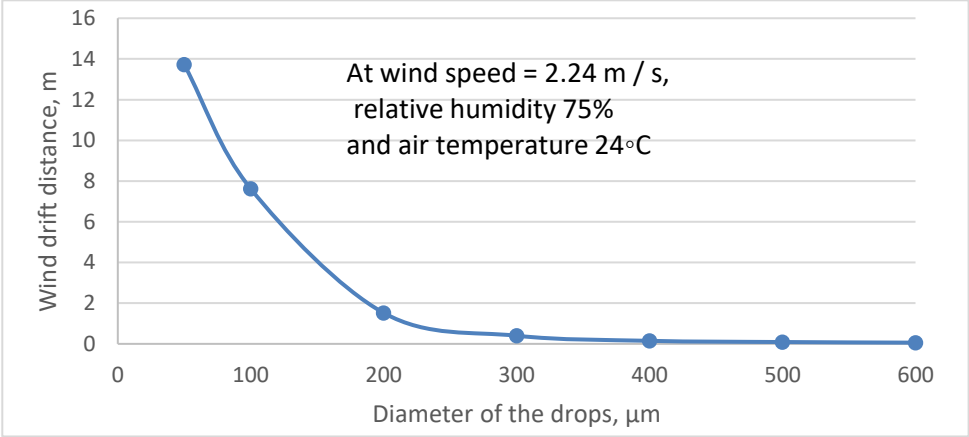


Fig. 3.5. Wind drift distance of the drops under the specified conditions depending on their diameter

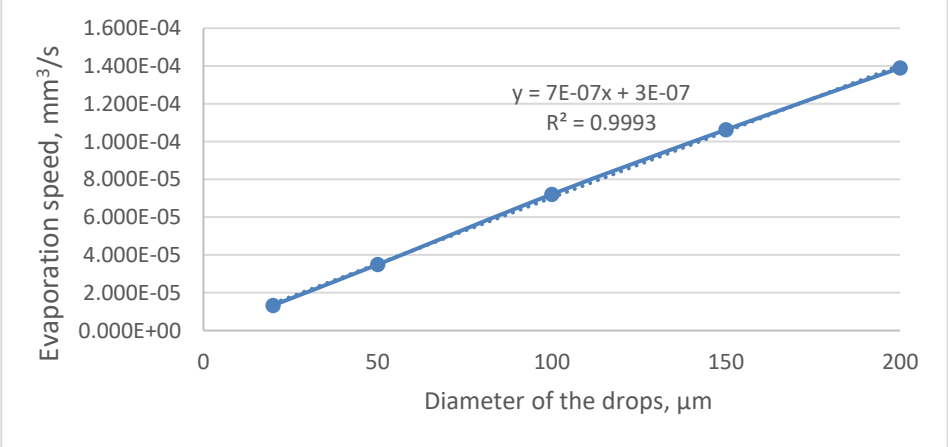


Fig.3.6. Evaporation speed from the surface of the droplets depending on their diameter

Theoretically, the required consumption of working fluid for an event can be determined taking into account the area of the treated object, the average volume diameter of the drip spectrum, agronomic requirements for drip density and losses of working fluid.

$$Q = \frac{S.n(1+k).D_v^3}{\eta}$$

where *S* is the frontal area of the treated site per hectare, m^2 / ha;

n - density of the drip coating according to the agro-technical requirements, pcs/cm2;

k - ratio of the density of the drip coating on the back to the front;

D_v – mean volume diameter of the drops среднообемен диаметър на капките, *mm*

η – percentage of working fluid utilized as intended, *%*

$\eta = 100 - \eta_d - \eta_e - \eta_{nt} - \eta_{fd}$,

η_d is the percentage of the air drip mixture carried to the sides of the sprayed object;

η_e - the percentage of losses from evaporated drops of working fluid;

η_{nt} - - the percentage of losses from drops that did not fall on the treated object;

η_{fd} - the percentage of losses from dripping of the drops.

Pesticide consumption rates are usually given per unit area. The real area treated changes with the development of the treated site, variety and cultivation technology. The actual consumption rate of a preparation (R) can be determined on the basis of the expression:

R = Ret. kr, where Ret is the label dose of the preparation and kr is the reduction factor.

The reduction coefficient will depend on the specific conditions, the treated object, the requirements of the struggle and the conditions under which and for which the cost norm is determined. The task for optimization consists in substantiation of a cost norm realizing effective plant protection with minimal ecological consequences and financial costs.

DETERMINATION OF THE TAPE SHAPE AND PARAMETERS OBTAINED BY A ROTARY SPRAYER

Rotary sprinklers generally create a circular torch. We build the mathematical model of the process under the assumptions that we know: the law of distribution of the droplet flow at the central angle α, deg of the torch $f(\alpha)$; the law of distribution of the flight distance of the droplets $(f(\rho))$ depending on the radius *r,m*; the flow rate of the spraying system *Q, l/min*; the consumption of working fluid *q, l/ha*; zero wind speed; constant height above the sprayed object *h, m*; horizontal surface of the sprayed object and working speed of the machine *V, m/s*.

The probability *P* of falling of working fluid on an elementary site can be defined as the product of the probabilities of falling in the range of the elementary angle $d\alpha$ and radius *dr*.

$$P(df)=f(\alpha)d\alpha.f(r)dr$$

The intensity of the amount of liquid falling on the elementary site per unit time can be found by the formula:

$$I= Q\, f(\alpha)f(r)/r,$$

and the amount of working fluid (consumption of working fluid) fell on the elementary site - $qF = It$

$$q_F = \int I\, d / V_m$$

Using the tray shown in Chapter 2, the differential fluid distributions for rotary sprinklers were obtained: Micromax III at two speeds and a modified Micromax III at three speeds. It can be seen that in the original version the distribution depends on the speed (Fig. 3.7), while in the sprinkler modified by us the shape and nature of the distribution do not change at different speeds (Fig. 3.8).

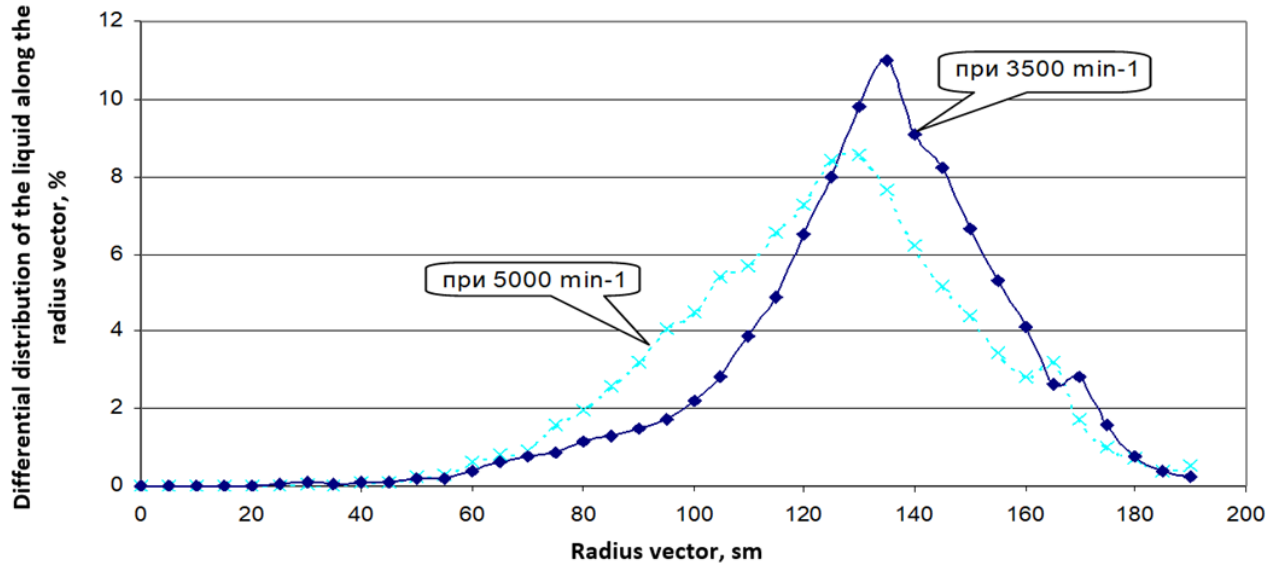


Fig.3.7. Percentage volume distribution of working fluid over the radius vector of a Micromax III rotary sprayer at two operating speeds

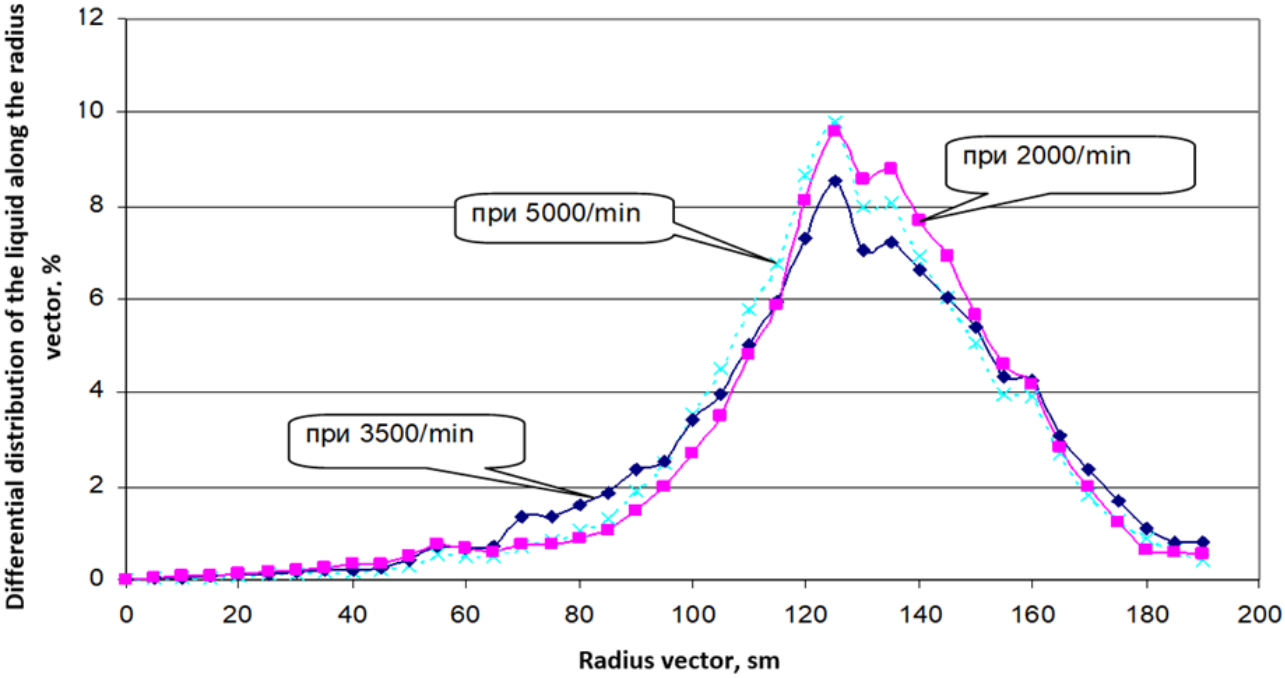


Fig. 3.8. Percentage distribution of working fluid volume over the radius vector of a modified Micromax III rotary sprayer at three working speeds

The obtained experimental data were approximated and on their basis in Mathcad environment the intensity of distribution of the working fluid along the radius vector of a rotary sprayer (Fig. 3.9) and on the basis of the general view of the analytical model shown in Fig. 3.10 is constructed the type of the spatial intensity of the distribution of the working fluid in a rotary sprayer (Fig.3.11)

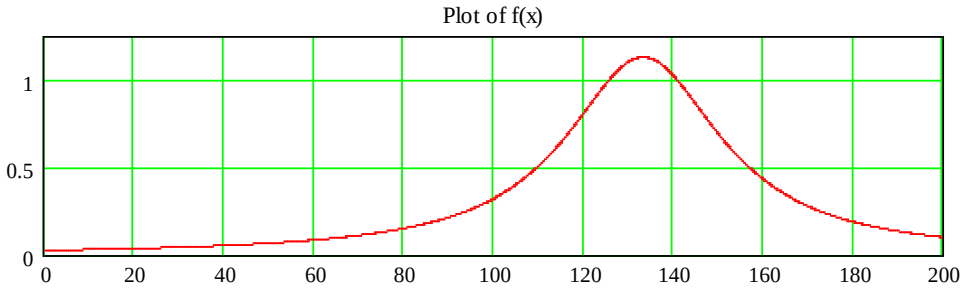


Fig. 3.9. General view of the intensity of distribution of the working fluid by radius the vector of a rotary sprinkler

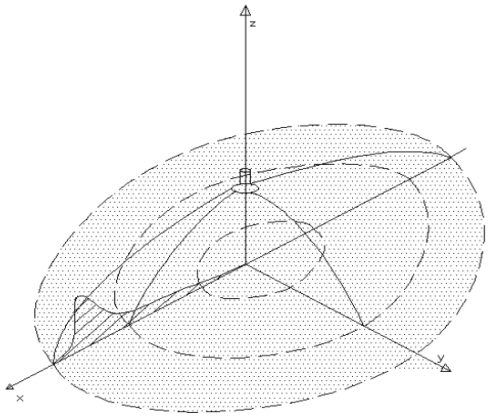


Fig. 3.10 Modeling the distribution of working fluid in a rotary sprayer

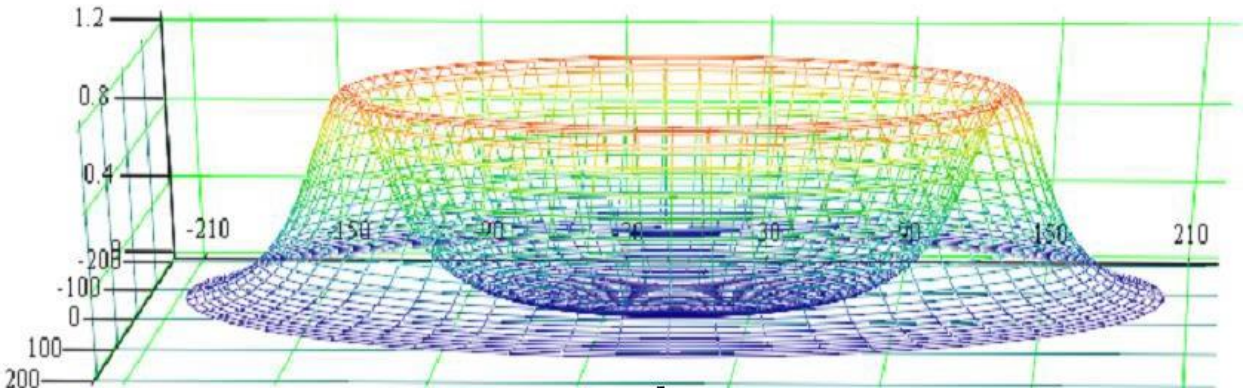


Fig.3.11. General view of the spatial intensity of the distribution of the working fluid in a rotary sprayer

CONCLUSIONS

1. The developed structure of the elements of the process of spraying a rotary sprayer allows it to be studied comprehensively and to get a clear idea of the phenomena that occur when the drops are detached from the spraying element and their movement to the treated objects.

2. The force generated by the mass of the drop is relatively small compared to other forces acting on the drop.

3. The calculated value of the velocity of the working fluid at the edge of the disk is 10% of its tangential velocity. In order to avoid this unfavorable effect, channels have been formed at the periphery of the disk with the developed sprinklers.

4. When spraying liquid with rotary sprinklers, depending on the flow rate of the working fluid, the size of the sprayer, the speed of rotation and the physical properties of the liquid, three

modes of operation are observed.

5. The diameter of the droplets in the first mode of operation is most influenced by the speed of rotation and less by the physical properties of the liquid and the radius. The formed drops are basic and satellite drops, as the diameter of the latter is 2.5 times smaller.

6. In the second mode, all the drops that are formed are "secondary", ie they are separated from the liquid fibers and not directly from the periphery.

7. The conditions under which the working fluid is switched from one mode to another are different for disc and drum sprayers.

8. The diameter of the drop is most influenced by the diameter of the sprayer. As it increases, the diameter of the drops decreases. As the flow rate of the working fluid increases, the diameter of the droplets increases.

9. Of the physical properties of the liquid, the most significant influence is exerted by the surface tension, especially in highly viscous liquids. The larger it is, the larger the droplet diameter under the same other conditions.

10. The third mode is essentially a polydisperse spraying mode, similar to the spraying obtained with conventional sprayers (hydraulic and pneumatic).

11. In order to take advantage of rotary spreading, it is necessary to work within the first and second spreading modes.

12. The flow rate of the sprayer has a decisive influence on the diameters of the resulting drops and until the production of monodisperse or polydisperse spraying.

13. It was found that in the free movement of the droplets in the transition between the sprinkler and the treated surfaces, the droplets with different masses have the same first integrals of motion, laws of variation of velocity and trajectories of motion.

14. There is a possibility to justify a cost norm implementing effective plant protection with minimal environmental consequences and financial costs.

15. The use of drops with a diameter of 0.180-0.200 mm are recommended in terms of their ability to carry and the rate of evaporation of the working fluid.

16. The general appearance of the spatial intensity of the distribution of the working fluid in a rotary sprayer has the shape of a crater.

17. In the original version of the Micromax III sprayer, the distribution of the working fluid depends on the speed, while in the modified sprayer the shape and nature of the distribution do not change at different speeds.

Chapter 4. RESULTS AND ANALYSIS OF EXPERIMENTAL RESEARCH RESULTS OF STUDY OF THE POWER CONSUMPTION

The Micromax III rotary sprayer is manufactured by the English company Micron Sprayers Ltd. It is powered by an electric motor, which is powered by the tractor's electrical system. It is structurally envisaged to change its speed by moving the drive belt.

In Fig. 4.1. the value of the power consumed starting and operating current in the three operating modes of the sprayer when working without working fluid is shown. As the speed increases, the starting and operating currents logically increase. At the same time, the increase in the starting current is twice less when switching from 2000 to 3500 min^{-1} than at 3500 to 5000. The situation is exactly the opposite with the current in operating mode.

Up to 50% is the increase in power consumption when changing the speed of rotation, fig. 4.1., As an increase in flow rate of 0.6 l / min has a relatively small effect on the increase in consumer current. There are three rotation modes in the Micromax III sprayers. These speeds

are structurally envisaged to be 2000, 3500 and 5000 min^{-1}. Under the influence of the working flow fluid that creates resistance to the drive system, the speed decreases with increasing flow rate, while it is insignificant at 2000 and 3500 min-1 and significantly higher at maximum speed (Fig. 4.2.)

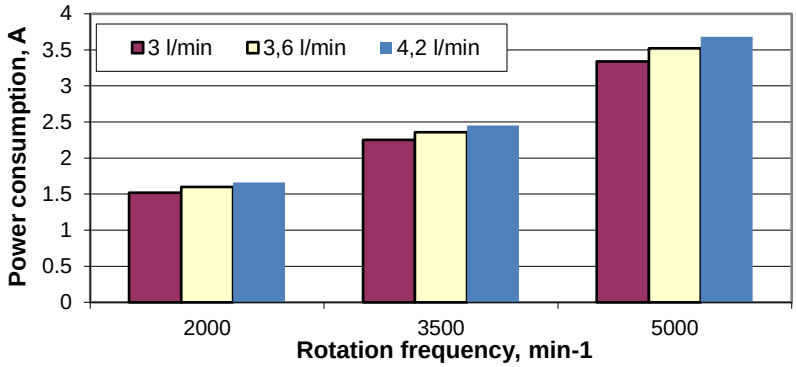


Fig. 4.1. Power consumption at three operating modes of the sprayer and three flow rates of working fluid.

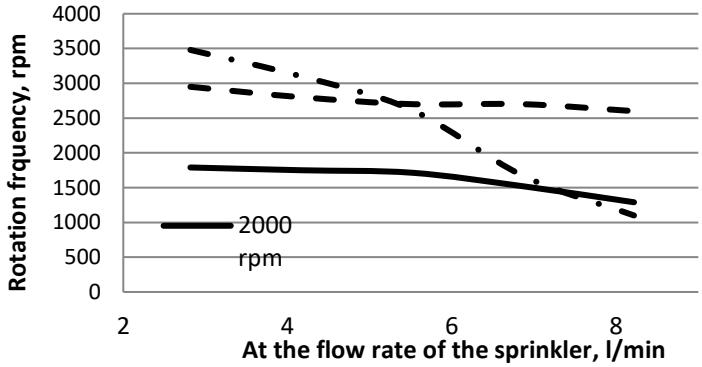


Fig. 4.2. Dependence of the speed depending on the flow rate of the sprinklers

RESULTS OF THE WORKING LIQUID DISTRIBUTION STUDIES

Duplicating the flow rate increases the spreading width by only 5% at the specified placement height and disc speed. This shows that the change in flow does not lead to a significant change in the diameter of the droplets, which would lead to a change in the parameters of the torch at the same speed.

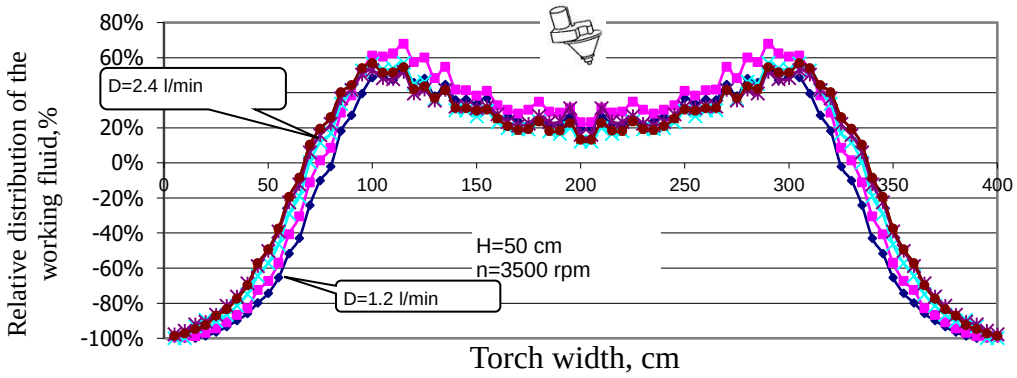


Fig. 4.3. Influence of flow on relative distribution

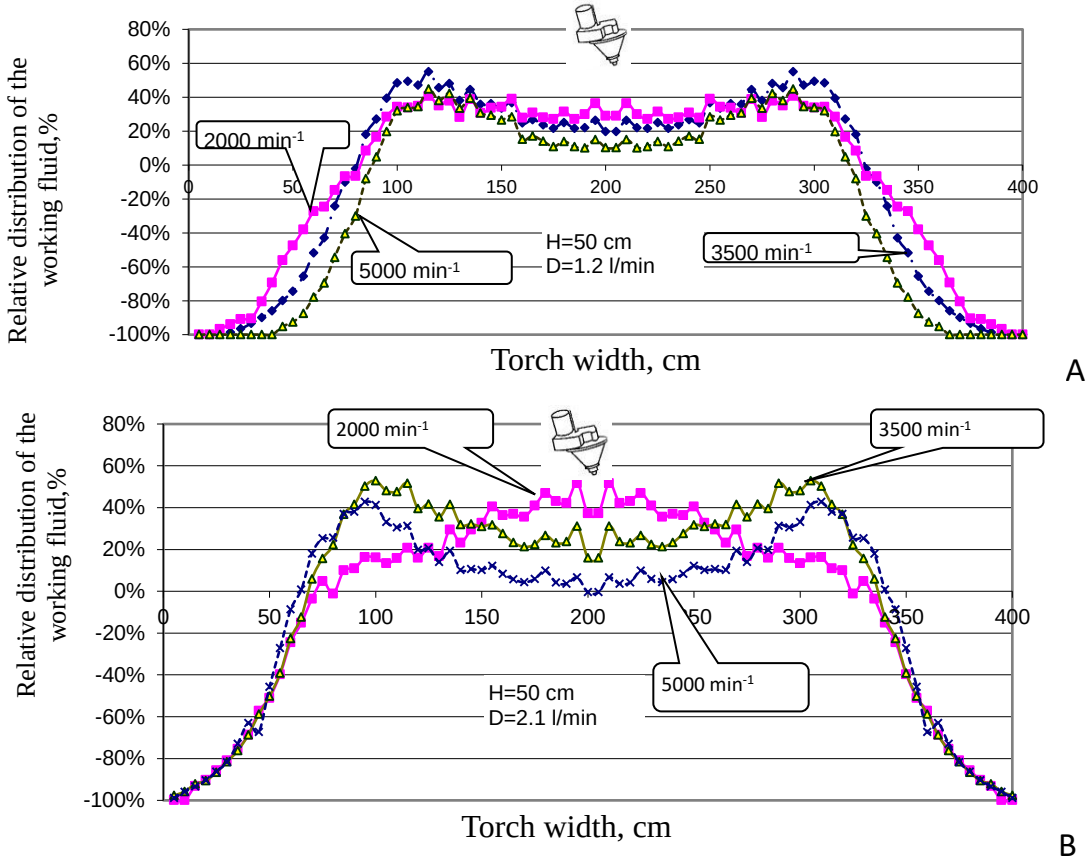


Fig. 4.4. Influence of rotation frequency on the relative distribution at different flow rates – A - 1.2 l/min; B– 2.1 l/min

The influence of the disk rotation frequency is slightly greater and is different in the central part of the torch and the periphery at different flow rates (Fig. 4.4). At a flow rate of 1.2 l/min with increasing speed, the diameter of the torch decreases as the transition from maximum intensity to the end of the torch is steeper than in other modes and the torch is more concentrated in circular tape.

As can be seen from fig. 4.5. two possible different spray intervals are clearly distinguished. A distance between these sprayers along the length of the boom of 0.85-1.05 m provides the requirements for all modes of operation of the sprayer.

The same result is obtained when using the second possible interval at 1.4 m. The second deployment step allows the number of sprinklers used to cover the same working width to be reduced by 1/3. With a predominant mode of use of 2000 min^{-1} (Fig. 4.5) and a flow rate of 1.5-2.1 this deployment distance can be 1.05 or 1.55 m.

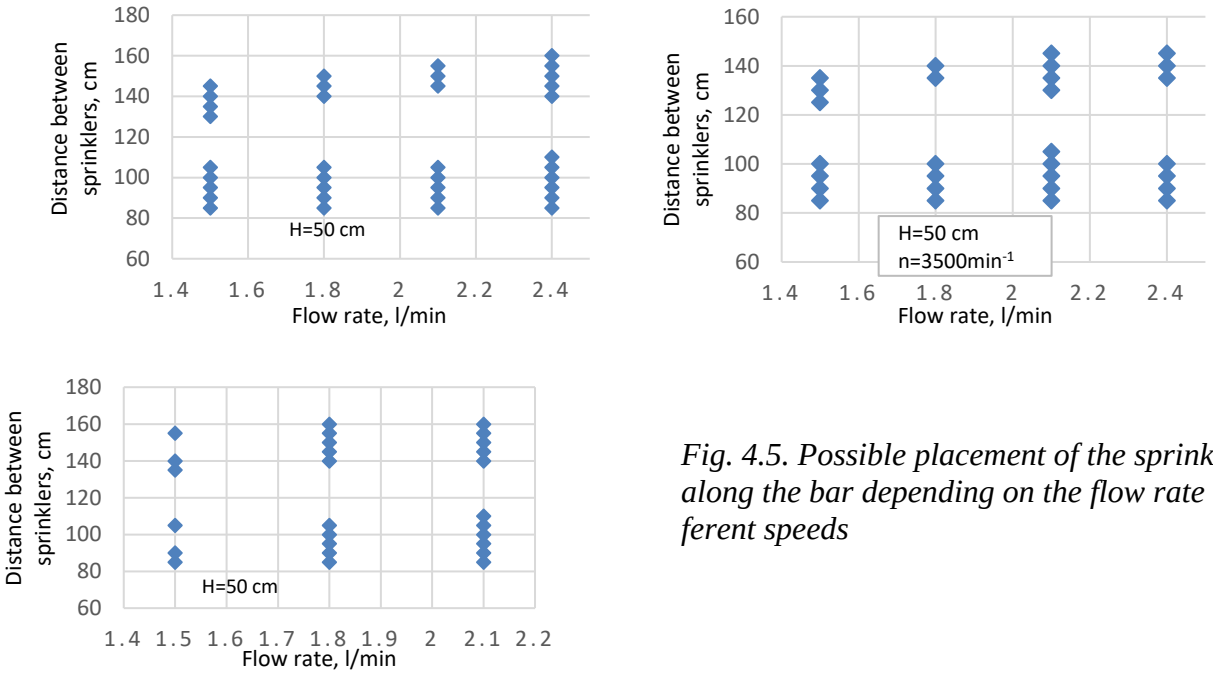
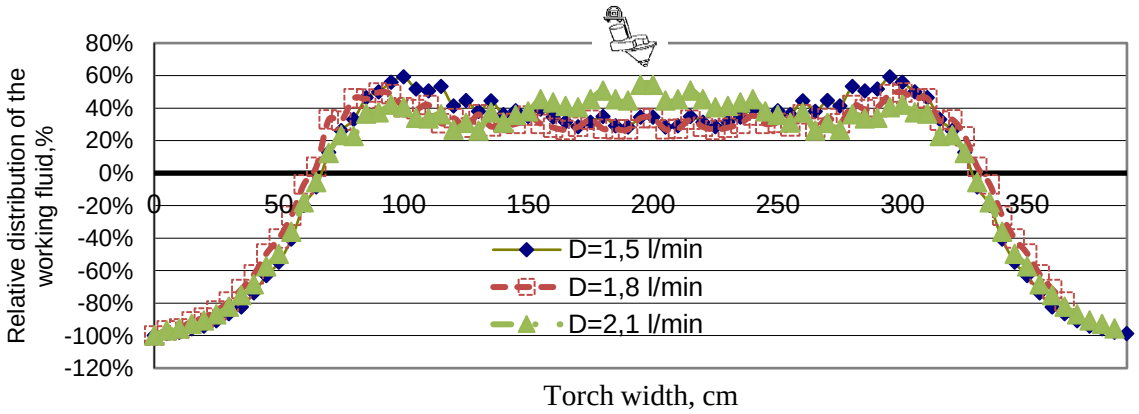


Fig. 4.5. Possible placement of the sprinklers along the bar depending on the flow rate at different speeds

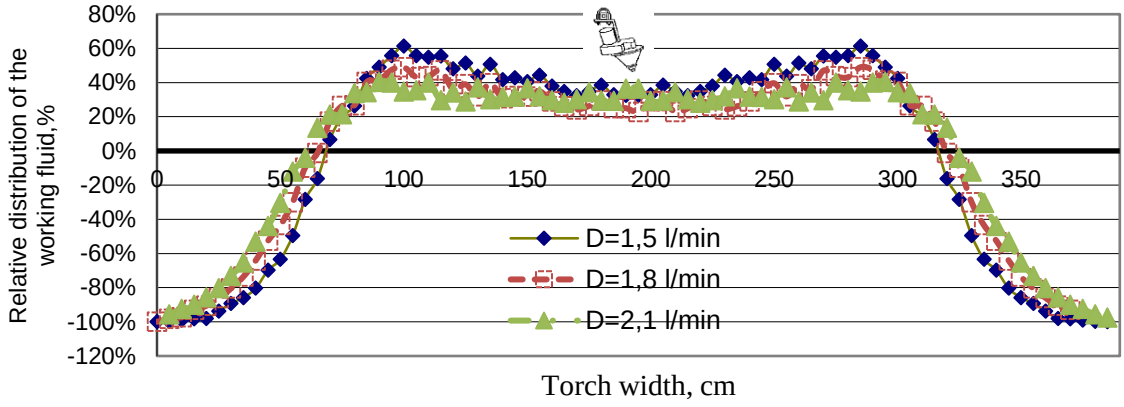
RESULTS OF THE EXAMINATIONS OF A MODIFIED SPRAYER MICROMAX III

The modified Micromax III sprayer presented in Chapter 2 was tested at three flow rates and three speeds at the same sprayer height (0.5 m) relative to the top of the capture surface to measure the working fluid distribution. The results are presented in fig. 4.6. the graphs show that as the speed decreases and the flow rate increases, the torch expands. This is probably due to the larger droplets that occur at this speed and they travel a long way due to their larger mass.

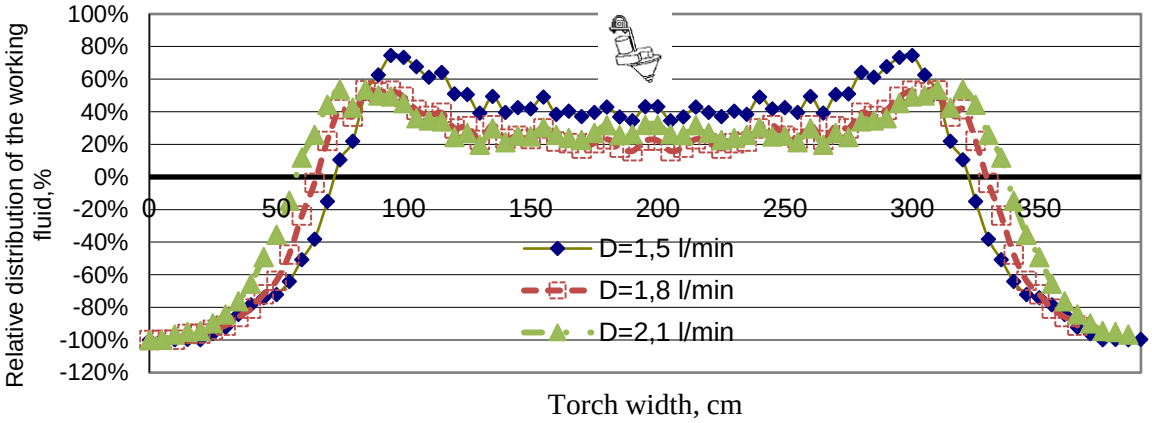
In fig. 4.7. the possible distances of the sprayers along the length of the boom are shown, at which the requirements for uniform distribution of the sprayed liquid are met. These possible distances are shown depending on the selected flow rate at an average speed of 3500 min^{-1}. Unlike the classic sprinkler, there are possible placement distances at a distance of 3 m. This shows that when using this sprayer and operating at flow rates above 1.5 l/min, it is possible to reduce the number of sprayers required at the same working width of the machine.



A



Б



В

Fig. 4.6. Influence of the flow rate on the relative distribution at the rotation frequency A - 5000 min^{-1}; B - 3500 min^{-1}; B - 2000 min^{-1}

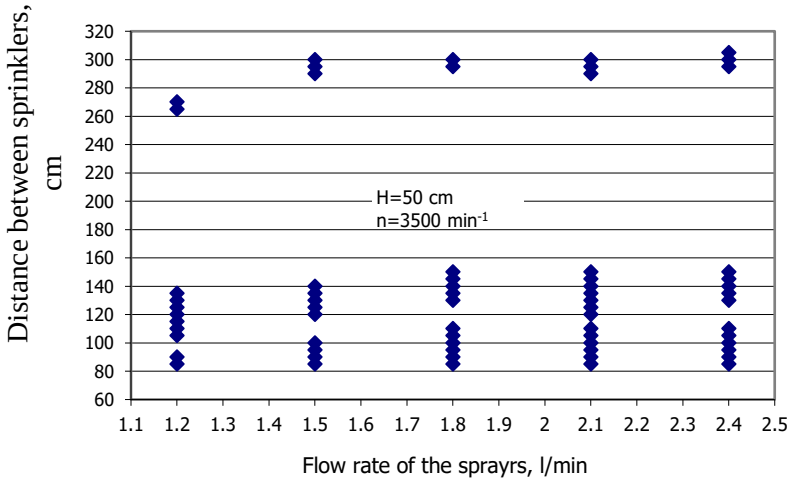


Fig. 4.7. Possible distances of the sprayers along the length of the boom depending on the flow rate at speeds of 3500min^{-1}

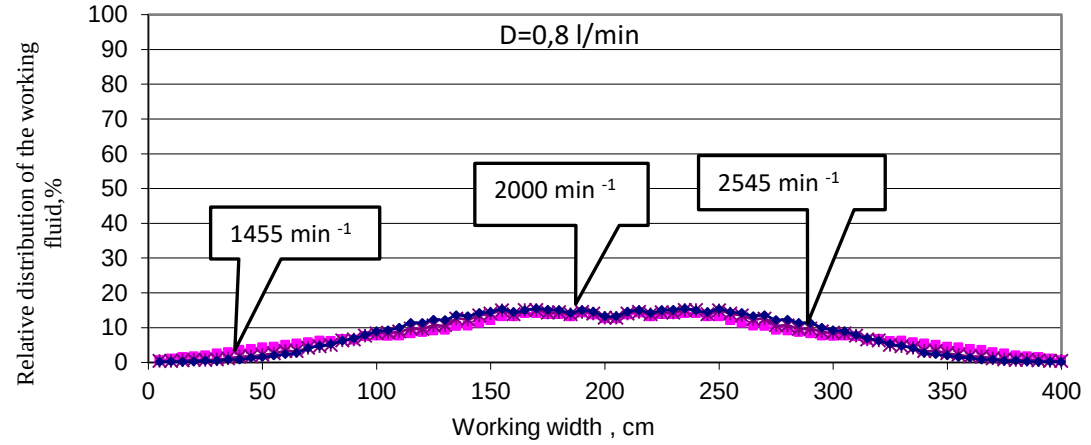
RESULTS OF THE INVESTIGATION OF SPRAYERS DEVELOP IN THIS WORK

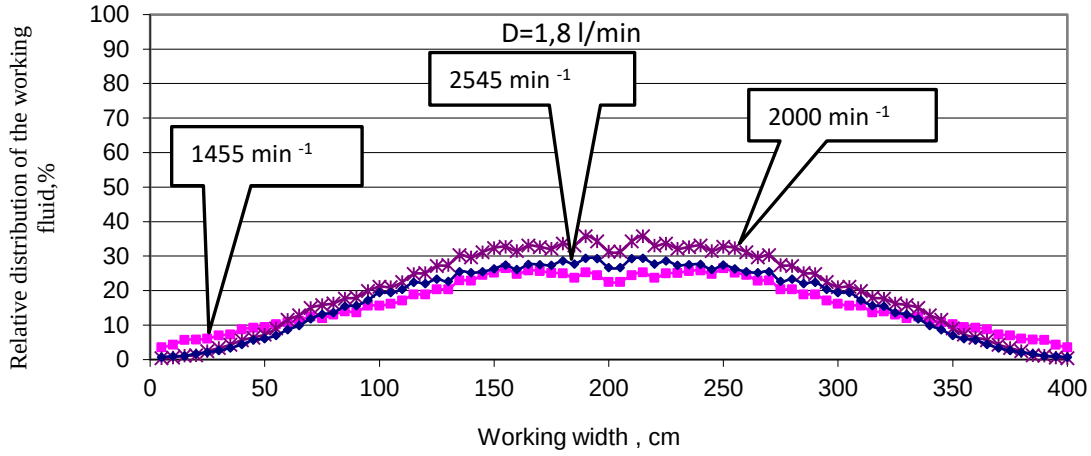
RESULTS OF INVESTIGATIONS OF SPRAYERS WITH A DIAMETEROF 254 mm

In fig. 4.8 shows the relative distribution of the working fluid over the width of the torch of a rotary sprayer, with hydraulic drive and diameter of the spraying working body 254 mm facing upwards. The three different speeds are shown with different types of lines and the different flow rates are shown

in separate graphs. It can be seen that as the flow rate increases, the amount of working fluid is concentrated towards the center of the sprayer, and at high flow rate and frequency the working fluid tends to be concentrated in a circular sector. At low speeds and flow rates, the torch width is greatest at the smallest deviation from the mean. As the flow rate increases, the torch width increases at all three speeds, with this increase being the highest at the lowest speed.

The lines of relative distribution at different speeds coincide or diverge in different areas with respect to the distance from the spreader while in fig. 4.9. the lines at different flow rates are not only not close, they do not diverge but they are quite far from each other. This seriously confirms the flow rate as a much more serious factor influencing the relative distribution of the working fluid along the width of the torch and respectively along the length of the rod on which the sprinklers are mounted.





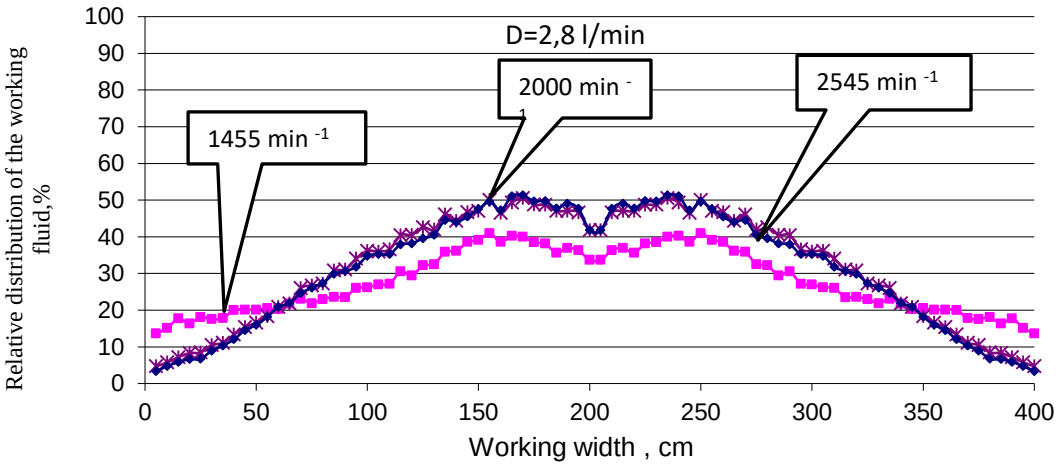
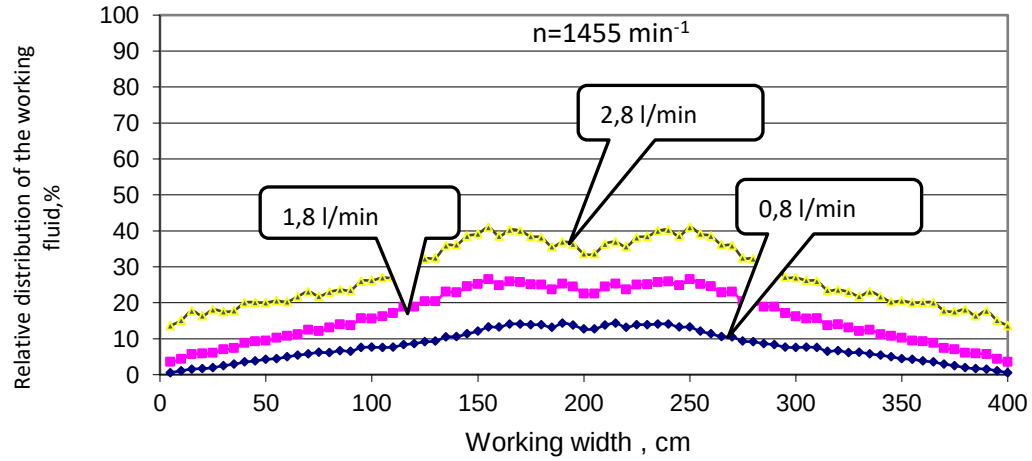
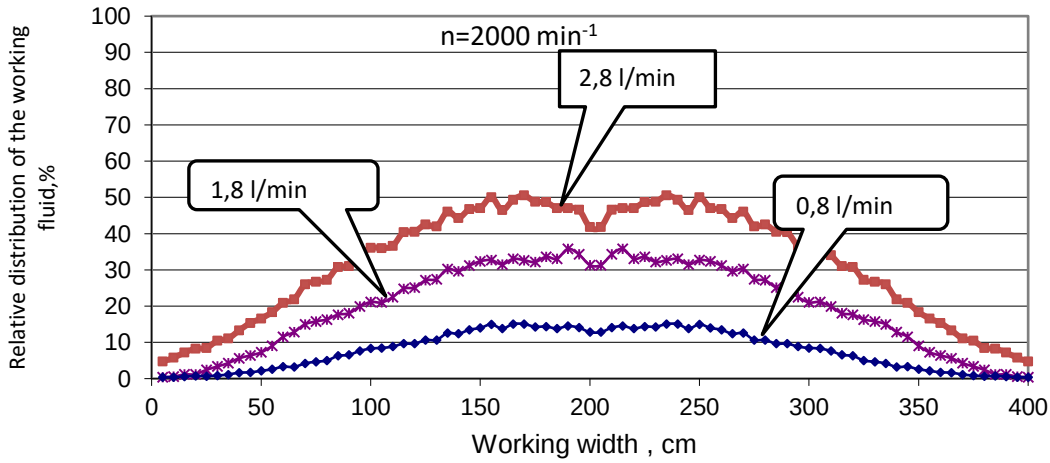


Fig. 4.8. Relative distribution of the working fluid over the width of the torch depending on the speed of rotation at different flow rates of the sprayer with di- meter 254 mm facing up





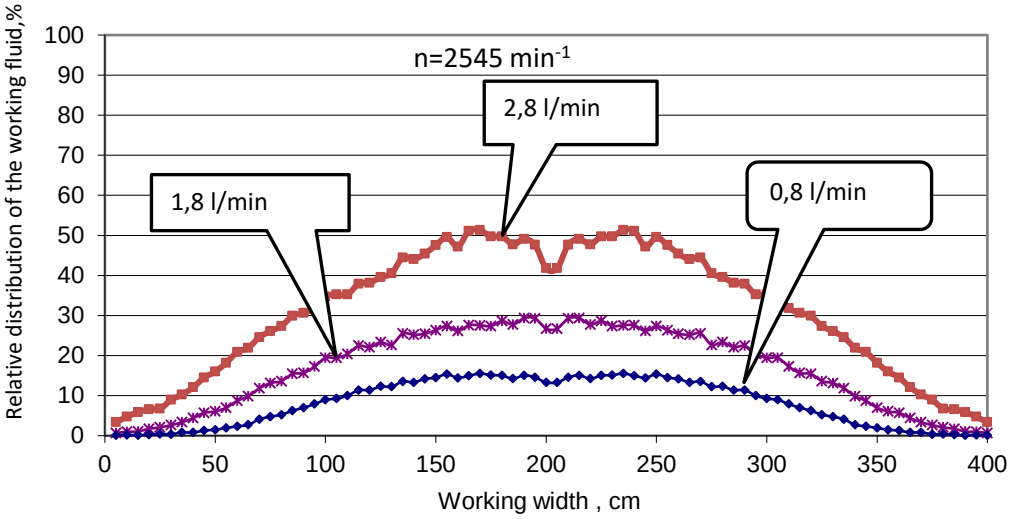


Fig. 4.9. Relative distribution of the working fluid over the width of the torch depending on the flow rate at different rotation frequency of the sprayer with a diameter 254 mm facing up

Fig. 4.10. shows the possible distances from each other of rotary spreaders along the width of the boom with the spreading working body facing upwards. The possible distances are calculated with a tolerance according to European quality requirements.

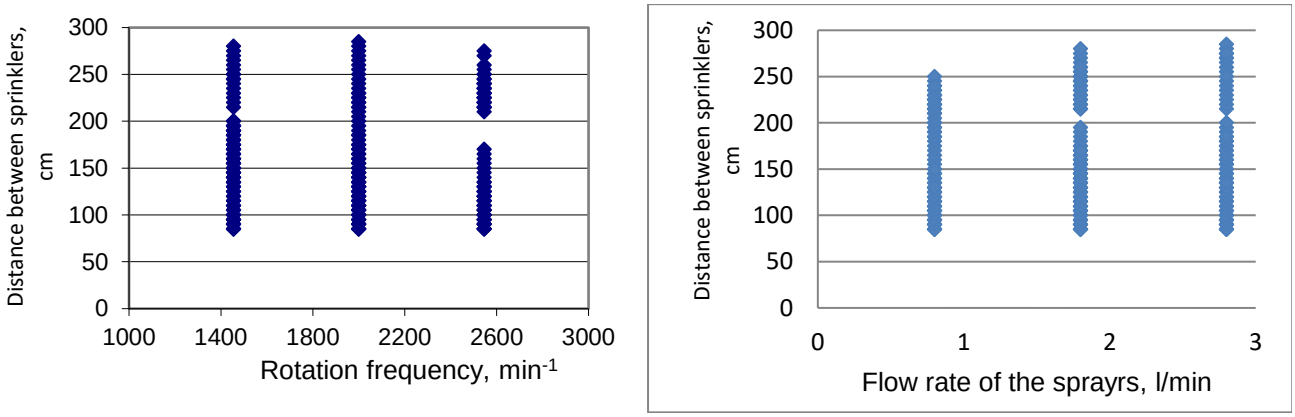


Fig. 4.10. Distance of possible position along the width of the boom of sprinklers with a diameter 245 mm facing up

In the case of spreading working bodies facing downwards, fig. 4.11. a sharper change in the distribution of the amount of fluid is observed. At low flow rate and speed there is a sharp increase in the liquid at distances of one meter from the sprayer and a sharp decrease in the amount of distances greater than one meter. At higher flow rates, this effect is less pronounced. At high flow rates, the amount of liquid under the sprayer is concentrated. At all three flow rates and speeds, the change in the amount of working fluid becomes much sharper, which reflects the possible deployment distances. It can be seen that with this type of sprinkler, it is not possible to select distances between the sprinklers that provide the necessary uniformity for all operating modes.

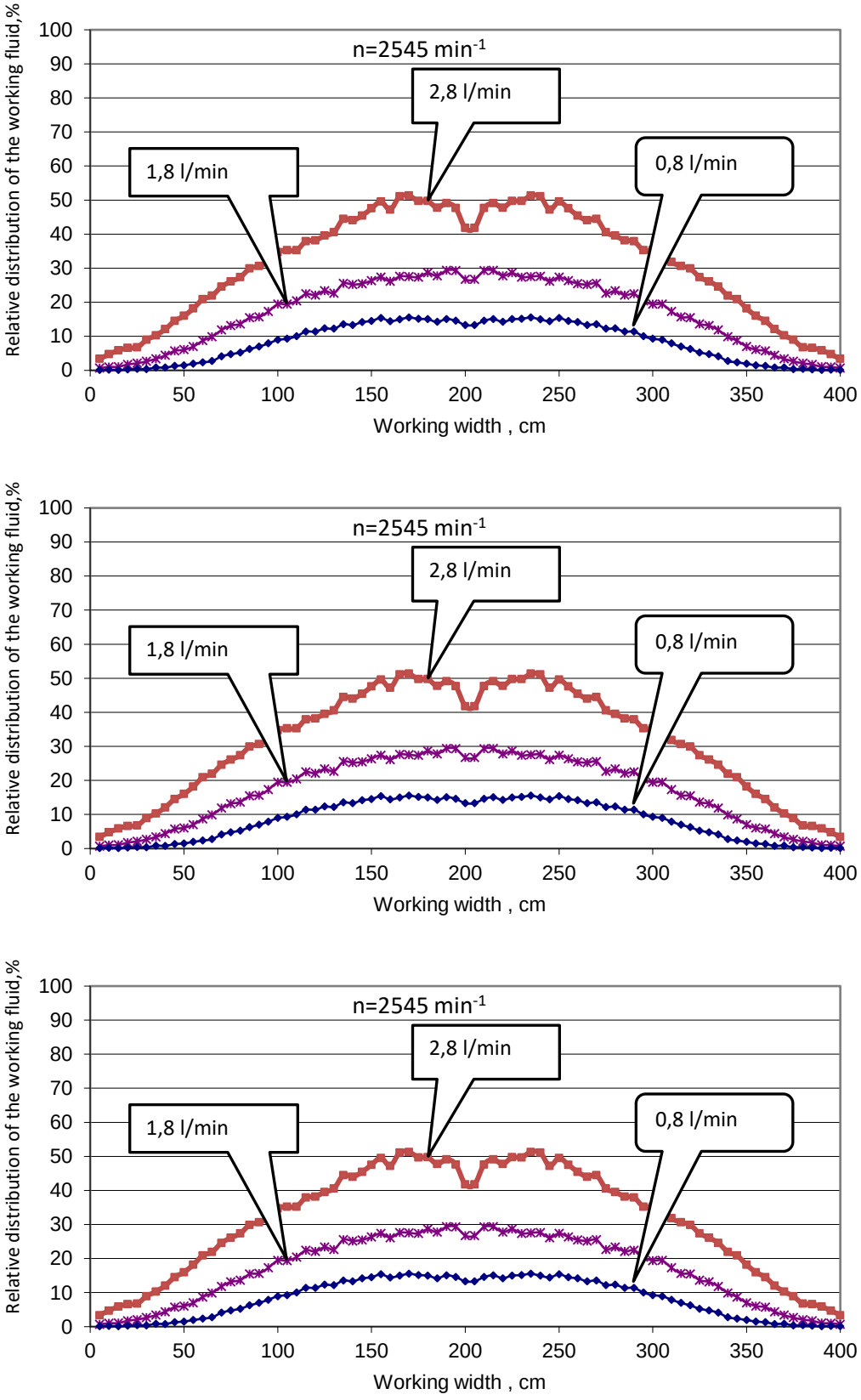


Fig. 4.11. Relative distribution of the working fluid over the width of the torch depending on the speed of rotation at different flow rates of the sprayer with diameter 254 mm. facing down

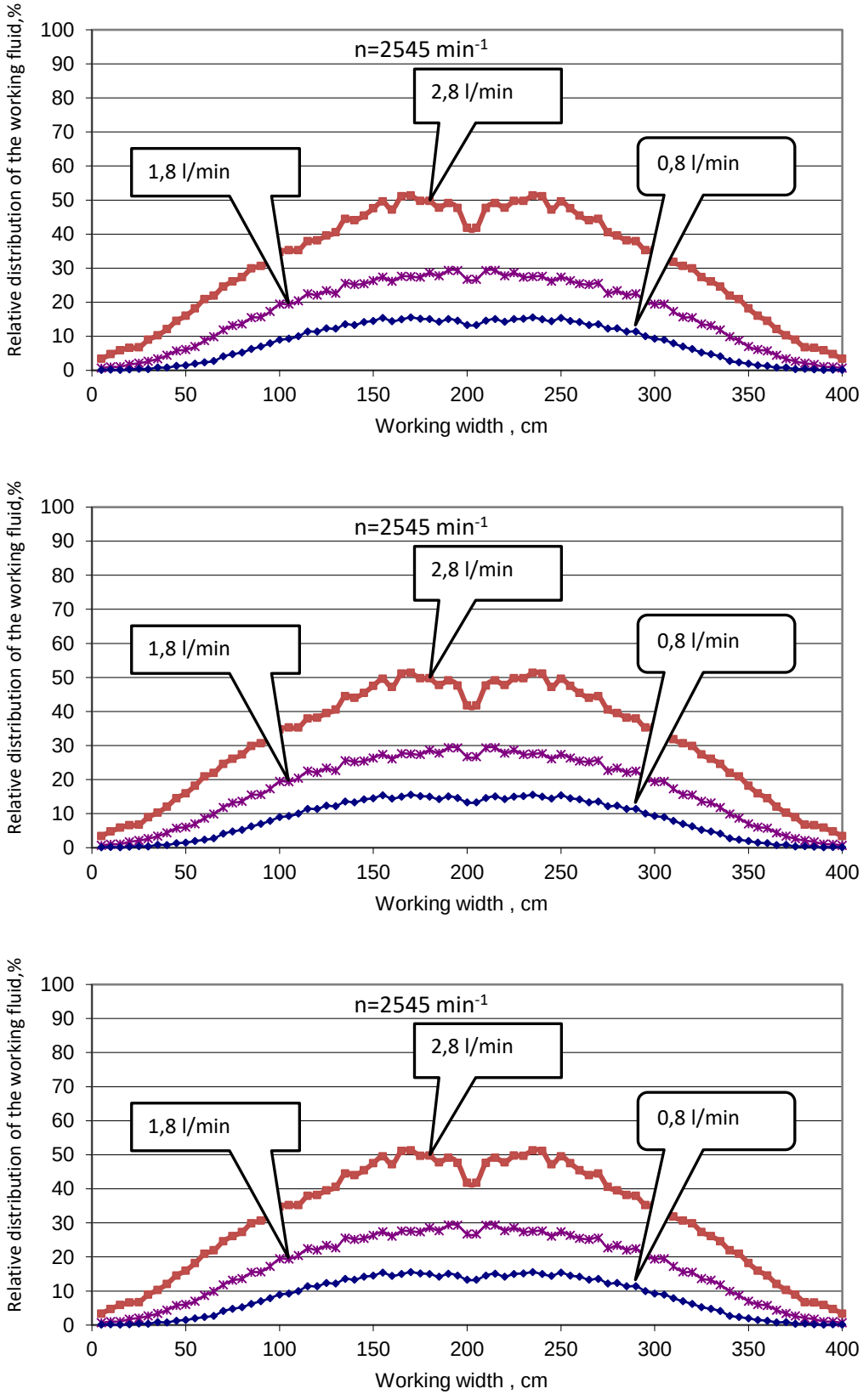


Fig. 4.12. Relative distribution of the working fluid over the width of the torch depending on the flow rate at different speeds of the sprinkler with diameter 254 mm facing down

The placement distances of the sprinkler mounted downwards fig. 4.13. are much more limited than the one mounted above in Fig.4.10. There is no stable operation here in the different modes and

the possible distances can be selected according to the modes in which the sprayer will operate. If the sprayer operates at a speed of 2000 min^{-1}, it is possible to install them at distances of 170 cm.

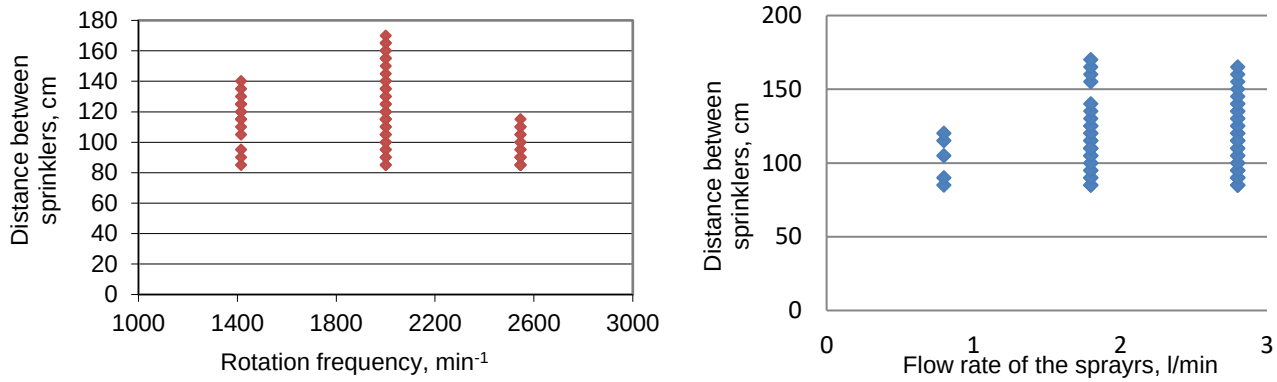
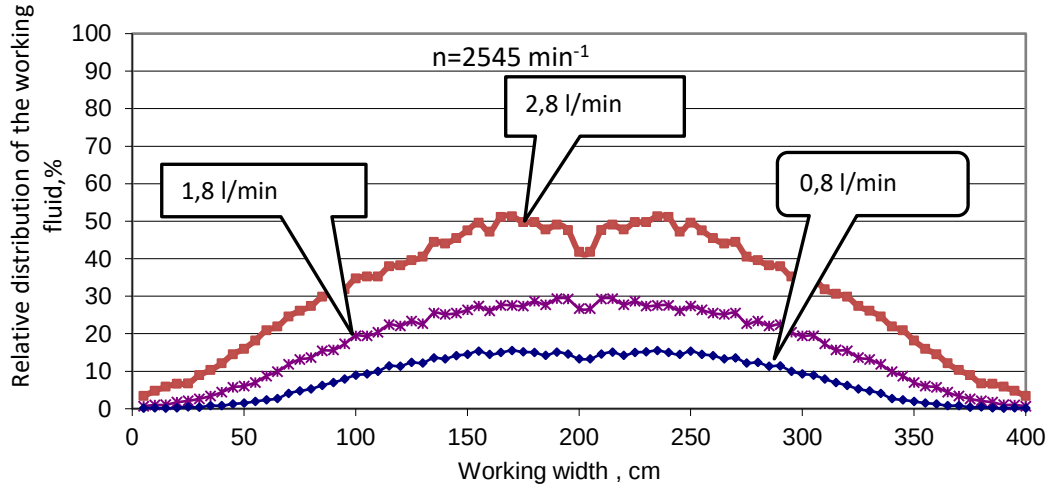
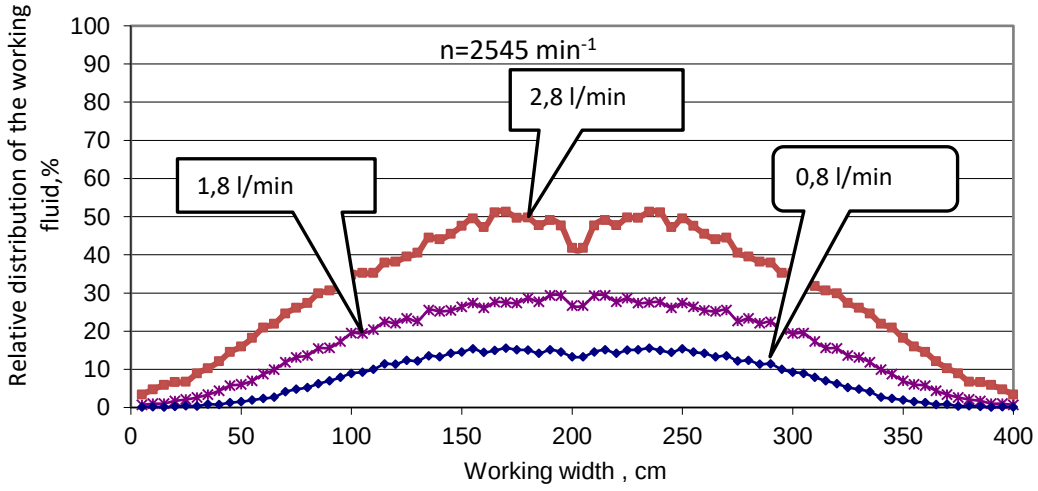


Fig. 4.13. Distance of possible position along the width of the boom of sprinklers with a diameter of 254 mm facing down

RESULTS OF THE RESEARCH OF SPRAYERS WITH A DIAMETER OF 330 mm

The study was performed according to the same methodology, with the difference that the speed was selected so as to obtain the same peripheral speed of rotation of the spreading working body. The lower peripheral speed with a larger diameter ensures the same working width of the sprayer.





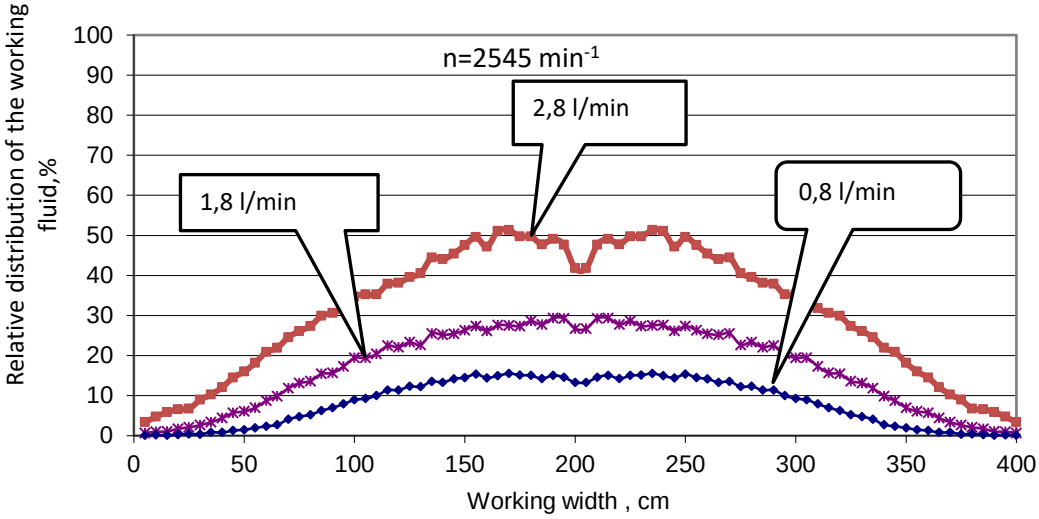
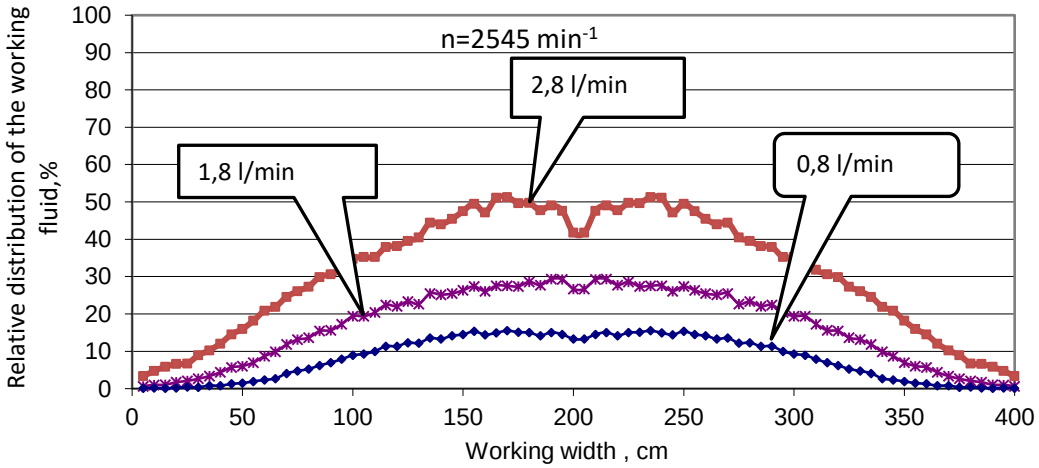
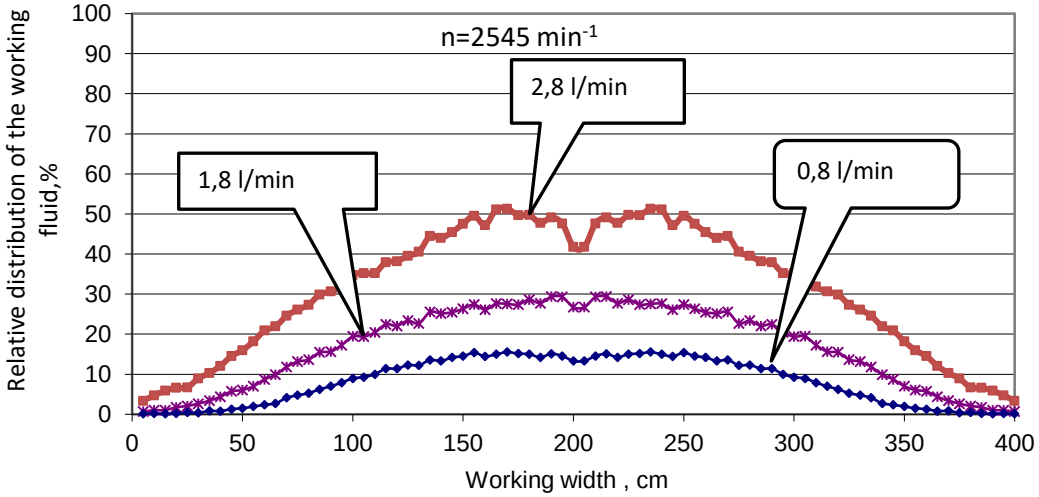


Fig. 4.14. Relative distribution of the working fluid along the width of the torch at different rotation frequency and flow rates of sprinklers with a diameter of 330 mm facing downwards

As the speed increases, these instantaneous values, which differ significantly from the torque distribution curves along the width of the torch, are smoothed out (Fig. 4.15), but in the very center of the sprayer there is an unevenness in all operating modes.





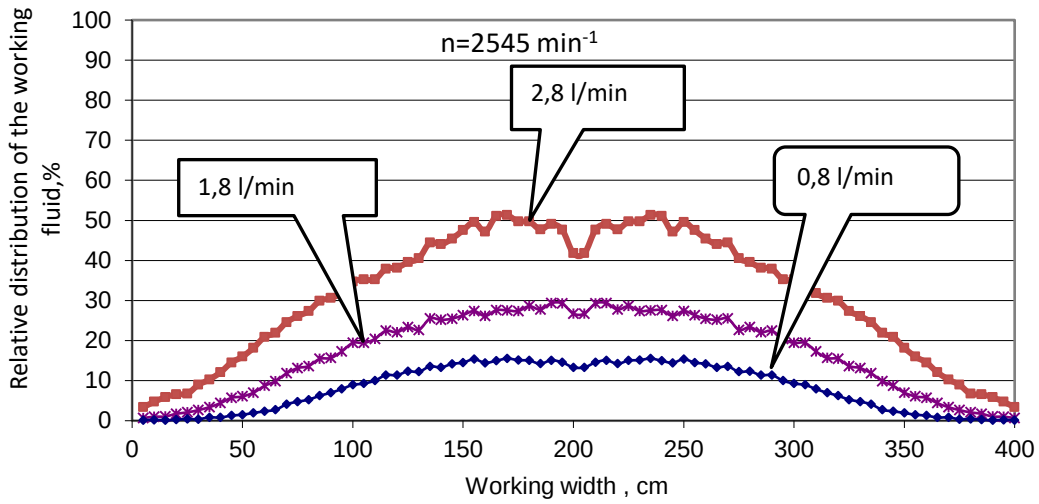


Fig. 4.15. Relative distribution of the working fluid along the width of the torch and step of possible position along the width of the boom of sprinklers with diameter 330 mm facing down at different flow rates.

Fig. 4.16 shows the impossibility of using this sprayer to select a distance between the sprinklers that meets the requirements for even distribution.

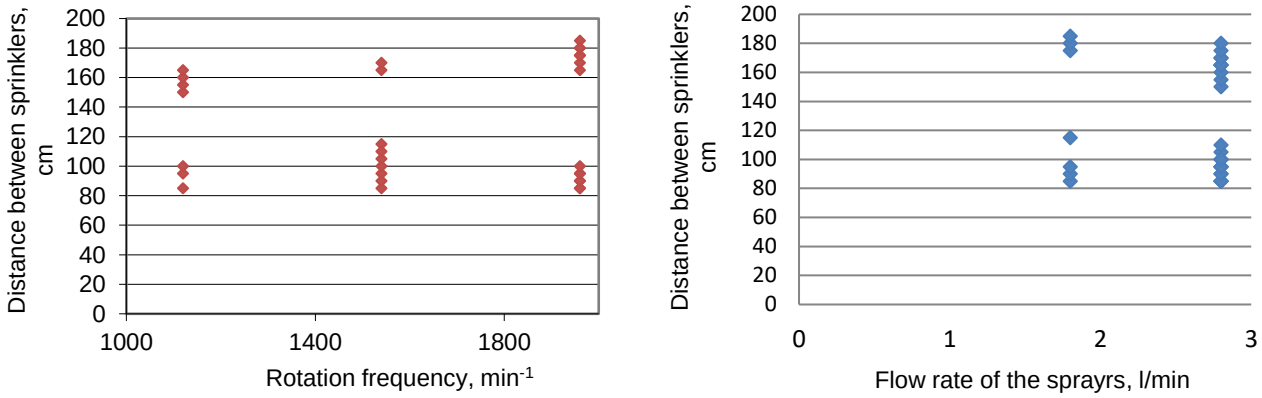


Fig. 4.16. Distance of possible position along the width of the boom of sprinklers with a diameter of 330 mm facing down

RESULTS OF THE STUDY OF MESH DRUM SPRAYERS

When estimating the relative distribution when using a mesh drum sprinkler (Fig. 4.17), it can be seen that its distinctive feature, unlike the sprinklers studied so far, is that the shape of the working fluid distribution is similar to that of the Micromax III sprinkler. Relatively less in the middle and at most a meter from the center. As with the lowest speed and the lowest flow rate is the most uniform. As the flow rate increases, the unevenness of the distribution increases.

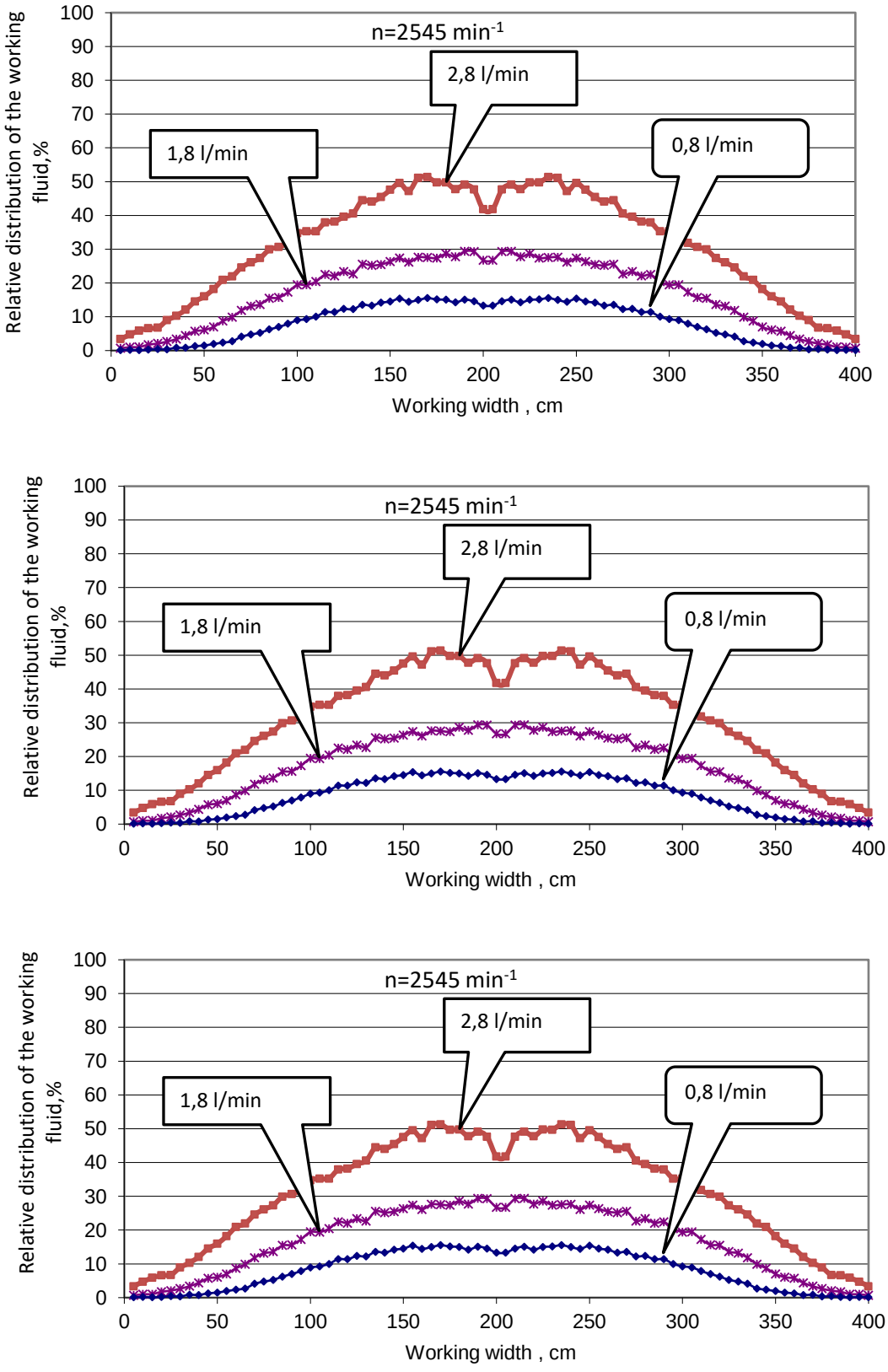


Fig. 4.17. Relative distribution of the working fluid over the width of the torch of sprinklers of mesh drum sprinklers with different flow rates.

The assessment of the possible mounting distance of this type of sprayer along the length of the boom shows that it is not possible to ensure the necessary uniformity of the distribution of the working fluid at different speeds and flow rates (Fig. 4.18).

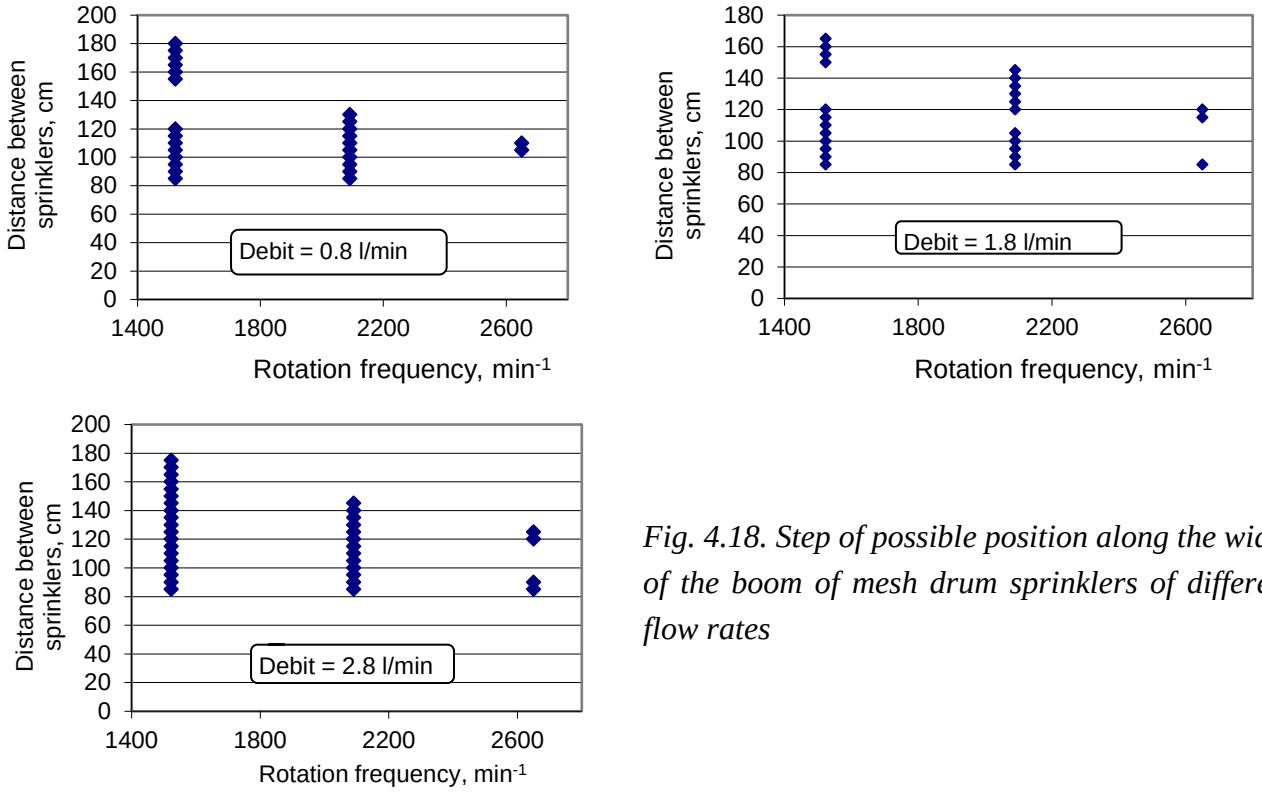


Fig. 4.18. Step of possible position along the width of the boom of mesh drum sprinklers of different flow rates

SHAPE TORCH FORM FOR DIFFERENT SPRAYERS

When observing the shape of the torch when leaving the periphery of the rotary spreaders in different modes, a change in the structure of the torch is observed. In most cases, up to two distinct zones are observed, but their presence or absence and parameters depend on the location of the sprinkler - up or down, the parameters of the mode and the shape of its periphery (Fig. 4.19).

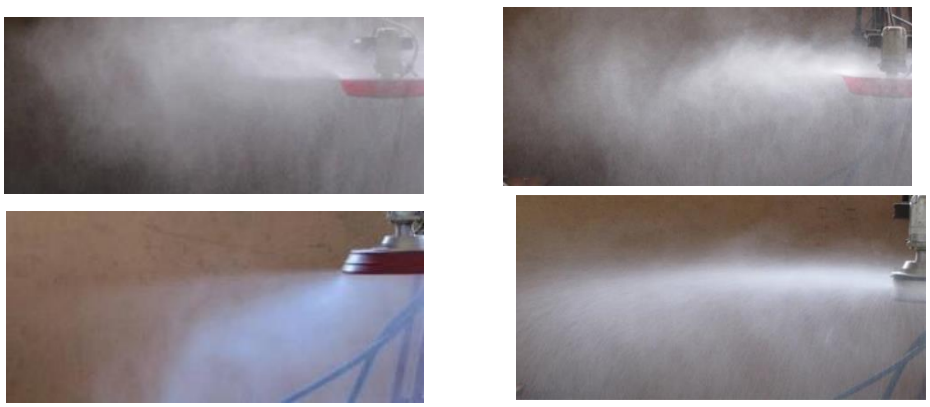


Fig. 4.19. The nature of the torch when leaving the periphery of different sprayers

To ensure these flow rates, the spray system must have a flow rate of 0.22-2.2 l / min according to a working width of 5 m. The parameters of the pump are determined based on the flow rate to be provided by the spray system, the flow rate required to mix the working fluid in the tank and the working pressure according to the characteristics of the sprinklers used.

When working with rotary sprinklers, the pressure that the pump must provide is only related to the stable dosing and must be 0.1-1 0.15 MPa. According to international practice, the flow required for mixing must be between 5 and 10% of the tank capacity. Based on this and the flow rate of the spray system, it is necessary that the flow rate of the pump is not less than 2.5 l / min and that it provides the above pressure.

Figure 4.34 shows a model of a sprayer equipped with the considered spraying system.

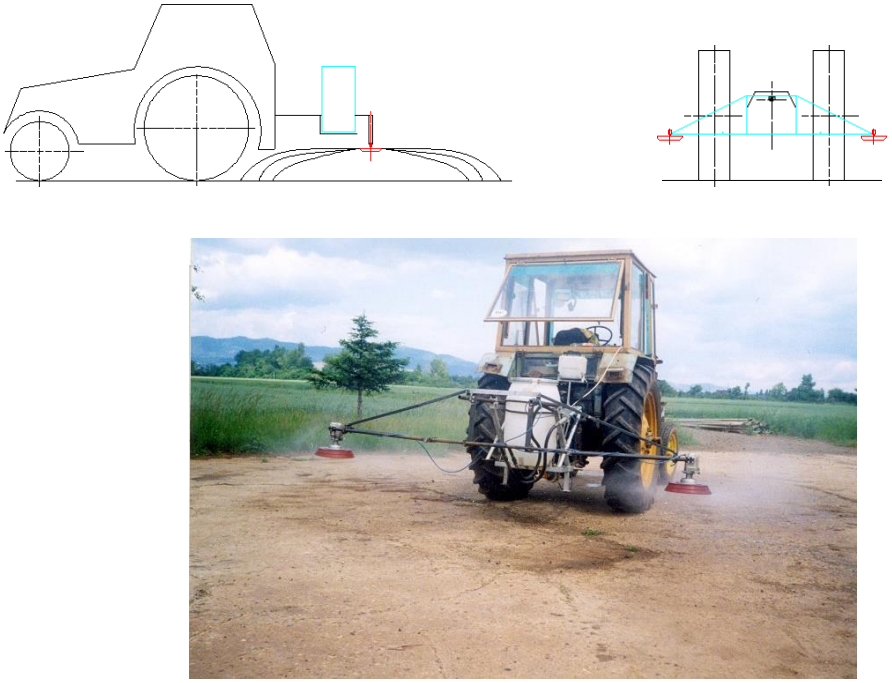


Fig. 4.34. Model of a sprayer with rotary sprayers

CONCLUSIONS

1. The starting current of the Micromax sprayer is twice that of the operating mode in all three operating modes. 50% is the increase in current consumption when the frequency changes rotation speed, as an increase in flow rate of 0.6 l/min has a relatively small effect on it.

2. As the flow rate of the sprayer increases, the speed of rotation of the sprayer decreases only in top gear. In the other two gears, this is reduced is relatively small in the study range. It should be borne in mind that working flow rates are at the beginning of the study interval.

3. Logically, by increasing the flow rate and the height of the spreader the rank of the torch increases, and this increase is relatively greater with increasing the height.

4. The developed software for simulating the distribution of the working fluid by the height of the boom allows the distribution to be optimized on the basis of the distribution of one sprayer. misreads the step of placing the sprinklers on the bar depending on the used cost norms and parameters of the desired drip coating. This creates the preconditions for selection of optimal configurations available to the sprinklers according to the specific cost norms, conditions and the enemy.

5. There are two possible deployment intervals for Micromax III sprinklers along the length of the rod. A distance between the sprinklers of 0.85-1.05 m provides the required in all operating modes of the sprayer. A second interval of available laying the rotary sprayers on the bar of 1.4 m, which can be used with up to 1/3 fewer sprinklers to cover the same working width. Modify The Micromax III sprayer allows, in addition to a step of 1.4 m and significantly larger step at the second interval (3 m) of placement of the sprinklers along the length of the rod.

6. The modes of operation and the constructive arrangement of the rotary sprinklers have an impact on the uniformity of the distribution of the working fluid over the width on the sprayed area.

7. The inverted rotary sprayer, with the diameter of the sprayer 254 mm, at a flow rate of 0.8 l/min to 2.8 l/min and a speed of 1455min^{-1} to 2545 min^{-1} provides transverse distribution of the working fluid

within the requirements for laying the sprinklers at a distance of 2.5 m from each other, even in most modes this distance reaches 2.8m.

8. The upturned rotary sprayer, with the diameter of the sprayer gan 330 mm, at a flow rate of 0.8 l/min to 2.8 l/min and a speed of 1120min^{-1} to 1960min-1 provides transverse distribution of the working fluid within the requirements for laying the sprinklers at a distance of 125 and 250 cm from each other.

9. The inverted rotary sprayer gives a very variable distribution under different regimes, as a result of which they have a significant impact on the possible sprayer placement distance. This is the reason why he can be selected only one (1.2 m) total distance of the sprinklers from each other for all studied regimes.

10. The results obtained show that the main influence on the distribution of The fluid in rotary sprinklers determines the speed of rotation and the location of the disk.

11. The graphical interpretation of the dependence of the distance of the deployment the rafters along the length of the bar from the modes of operation allows you to choose and more available in accordance with a working width determined for other reasons.

12. Almost the same quality of work and deployment step is obtained when scattering kvach with a diameter of 330 mm turned up with trimmed periphery. This shows that the shape of the periphery of the disk and their diameter in these models and the location of the sprinklers no affect the quality of their work.

13. When using a rotary disc spreader with a diameter of 254 mm, turn the below the maximum distance between the individual sprinklers in the different operating modes the boot can be 1.15 m.

14. When using a rotary disc sprayer with a diameter of 330 mm inverted below the maximum distance between the individual sprinklers in the different operating modes the boot can be 1.65 m.

15. In order to ensure the necessary cost norms, the spray system according to the bottoms width of 5 m must have a flow rate of 0.22-2.2 l/min at a pressure of 0.1-0.15 MPa.

CONTRIBUTIONS

The structure of the elements of the process of spraying the working fluid is made in the case of a rotary sprayer, which allows it to be complexly studied and obtained a clear idea of the phenomena that occur when the droplets are detached from the sprayment and their movement to the treated sites.

The influence of the parameters of the spraying process and the constructive ones has been established characteristics of rotary sprinklers on the transverse distribution of the working liquid

The possibility for using cost norms realizing effective protection with minimal environmental impact and financial cost.

It has been found that the starting current of the Micromax sprayer is twice as high as that in operating mode in all three operating modes, which must be taken into account when determining of the possible number of sprinklers driven by the tractor's electrical system.

The parameters of the distribution of the working fluid over the width of the boom depending on the operating mode of the sprayer.

A procedure has been substantiated and has been implemented programmatically to determine the possible distances positioning of the spreaders along the length of the boom depending on the distribution of the working fluid in different operating modes of the spray system.

The possible distances of the rotary sprinklers along the length of the boom have been determined.

It was found that the main influence on the distribution of the working fluid in the rotary sprinklers is the frequency of rotation and the location of the disk.

The optimal mode of operation and location of rotary sprayers to the boom sprayer depending on the design of the sprayer is justified.

Technology and technical means for work on the technology for controlled drip coating are substantiated.

A model of a plant protection machine with rotary sprinklers has been made.

PUBLICATIONS FOR THE DISSERTATION

1. Georgi Kostadinov, Elena Dimitrova, Milena Moteva. Modeling of the spray liquid distribution of rotary atomizers, Proceedings 11th International Congress on Mechanization and Energy in Agriculture. September 21-23, 2011, Istanbul, 108-112.

2. Dimitrova E., Trends in the development of spraying systems of plant shield machines, Proceedings of the International Conference on the Balkanieko 2016, Balkan Economic Reconstruction and Ecology, National House of Science and Technology, Sofia, April 7-8, 2016.

3. Elena Dimitrova, Ivan Mortev, Georgi Kostadinov. Transverse unevenness of spraying with a rotary sprayer with hydraulic drive, Bulgarian Journal of Crop Sciences, 2017, 54 (4), 20-27.

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