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The Most Simple and Readily Available Approach to Global Pesticide Pollution Prevention

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ROsá centrifugal atomizers ensure a six-fold reduction in the pesticide application rates and up to a forty-fold reduction in the soil contamination levels due to the efficient and reliable spraying.

Keywords: pesticide, environment, pollution, spraying, ROsá atomizers, Agromodul.

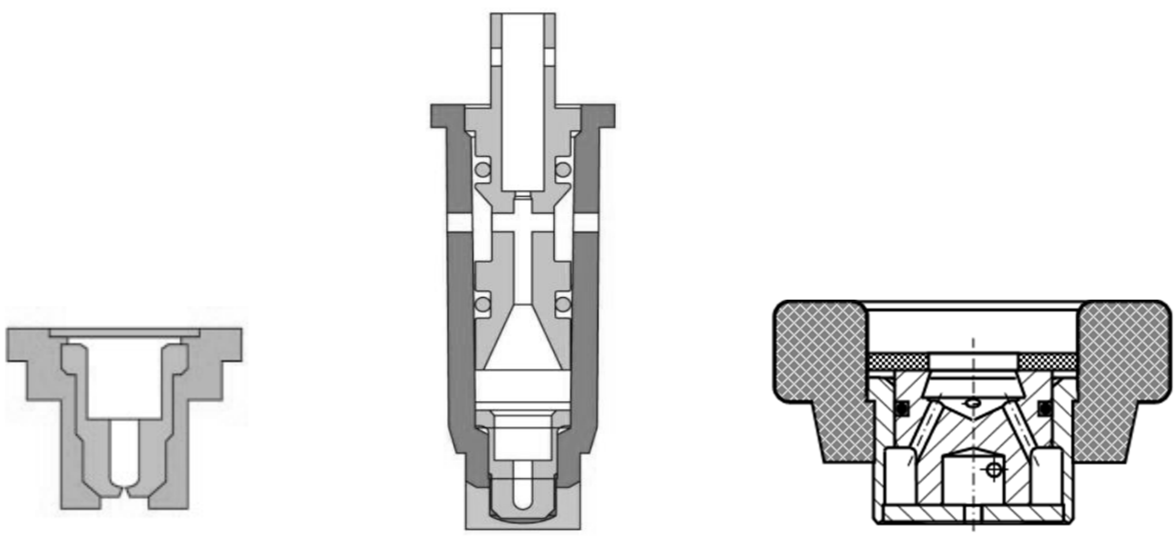
Based on recent advances in hydrodynamics of liquid dispersion, a centrifugal atomizer of a conceptually new design has been developed in Ukraine (Patent UA 24416). The centrifugal atomizer ROsá ensures the appropriate pesticide application due to forced deposition and retention of at least 80 per cent of the total volume of atomized droplets on the target plants. Thereby, the enhanced performance of the ROsá atomizers adds a new dimension to the chemical plant protection technology. For example, with the use of flat-fan or slit-type nozzles, the typical rates of the working fluid are from 200 to 300 L/ha, while with the centrifugal ROsá atomizers, only from 20 to 50 L/ha of the same working fluid are sufficient for optimum spraying efficacy. Accordingly, the less the working fluid flow rates require less quantities of the pesticides and that, in turn, results in less soil pollution.

For more than 17 years, in all regions of Ukraine, the ROsá centrifugal atomizers have been successfully used in a wide range of spraying systems, both of indigenous and foreign manufacturing. Over the years, the ROsá atomizers have proved their efficacy, durability, reliability, maintainability and safety in the field operations.

Scientific substantiation for the ROsá atomizer spraying parameters has been presented in more detail in the articles mentioned below [1]-[4].

1. ROsá Centrifugal atomizer

By way of comparison, Figure 1 shows the schematic diagrams of three different types of nozzles: a slit-type nozzle (a), an injector nozzle (b), and a centrifugal nozzle (c).



(a) (b) (c)

Figure. 1. Spraying nozzles for pesticides.

The designations of the ROsá atomizers and the working fluid flow rates corresponding to various travel speeds of the field sprayer are listed in the following table:

Working fluid flow rates, L/ha

Atomizer designation	Pressure, MPa	Flow rate, L/min	Field sprayer travel speed, km/h								
			6	9	12	15	18	20	24	30	40
P.03.0.3	0,3	0,3	**60**	**40**	**30**	**24**	**20**				
P.03.0.4		0,4	**80**	**53**	**40**	**32**	**27**	**24**	**20**	**16**	
P.03.0.6		0,6		**80**	**60**	**48**	**40**	**36**	**30**	**24**	**18**
P.03.1.2		1,2					**80**	**72**	**60**	**48**	**36**
P.03.2.0		2,0								**80**	**60**

The ROsá atomizers disintegrate the working liquid into the fine droplets less than 350 μm in size and disperse them at a pressure of 0.3 MPa. The droplets are subjected to forced deposition at a 0.5 m distance above the target surface and at a velocity of 2-3 m/s ensured by the flow of air, which is entrapped into the stream spray cone due to underpressure created around the axis of the swirled fluid flow.

The working liquid flow rate, the spray angle and the droplet sizes remain unchanged over the period of 7,000 hours of the ROsa atomizer operation, therefore, there is no need to control the working liquid expenditure. Single-stage filtering of the fluid through a mesh of 365 μm suffices the trouble-free performance of the spray nozzle. The ROsá atomizers have proved to be safe in operation.

2. <u>Efficient spraying</u>

Recent nozzle technology is placing an increased emphasis on achieving the maximal quantity of droplets to be retained on the plants in pesticide spraying.

The significant characteristic of spraying efficacy is **the droplet retention efficiency rate**, which is determined as the ratio between the volume of droplets retained on the plant surface and the total volume of dispersed droplets:

$$\eta_{0,5} = \frac{Q_y}{Q} \cdot 100, \ \%$$

where 0.5 is a distance from the nozzle to a hard target surface (meter).

Depending on wettability of the plant surface, the deposited droplets may acquire different shapes, as illustrated in Figure 2: (a) – a freely wettable surface; (b), (c) – sparsely wettable surfaces.

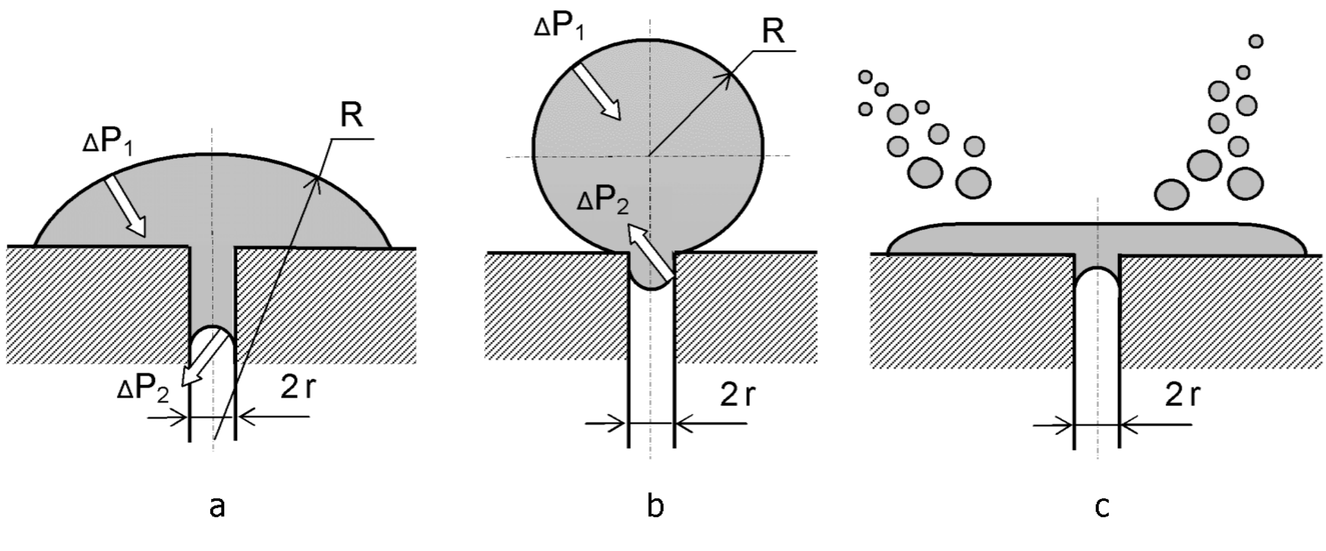


Figure. 2. Droplet shapes on the hard surfaces.

The droplets do not rebound off the plant surface when the kinetic energy $E_K = \frac{mV^2}{2}$ is less than the surface energy $E_П = \sigma S$, where $m = \frac{1}{6}\pi d^3 \rho$ is the droplet mass, V denotes the droplet velocity at contact, $S = \pi d^2$ is the droplet surface area, d is the droplet size, σ is the surface tension, and ρ is the viscosity of the working fluid. With $E_K > E_П$, the droplet (c) rebounds off the plant surface and slips off onto the ground, and it is actually lost in spraying, with the exception of the least quantity of fluid that remains as a patch on the plant surface being wetted.

Modern laboratory equipment with the laser instruments for diagnostics of the spray cone characteristics makes it feasible to measure the droplet sizes and velocities and also to estimate droplet retention efficiency rates.

Figures 3 and 4 show the velocities and the droplet volume distribution (respectively) for a centrifugal nozzle (1) and an injector nozzle (2), both operating at a liquid flow rate of 0.6 L/min and a pressure of 0.3 MPa, and both nozzles are placed at a 0.5 m distance above the target surface. The black line (3) corresponds to $E_K = E_П$.

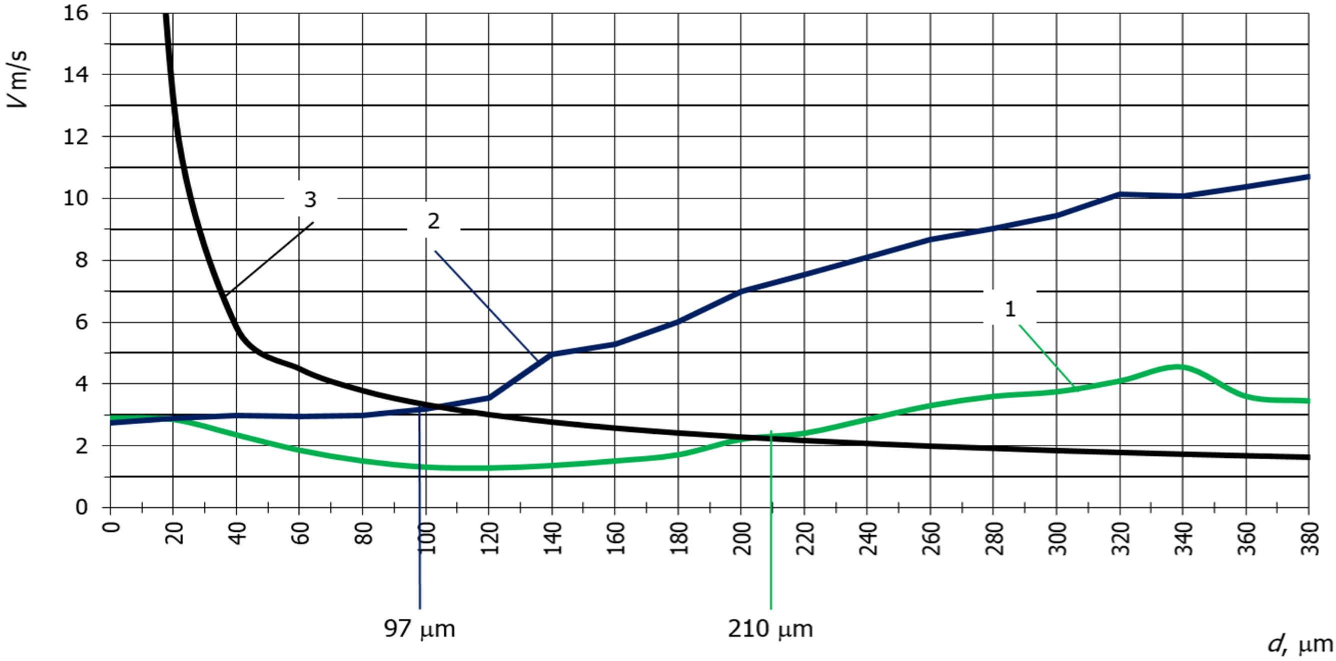


Fig. 3. Droplet velocities

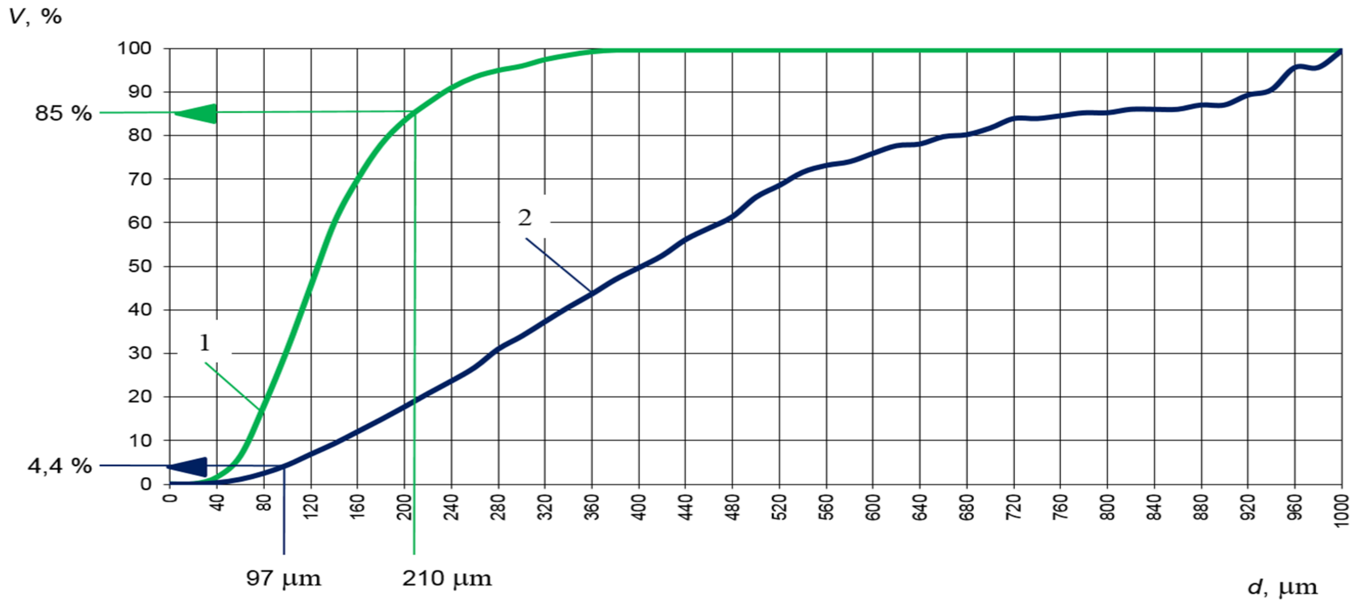


Fig. 4. Droplet volume distribution

The ROsá centrifugal atomizer ensures the deposition of droplets less than 210 μm in size without their rebounding off the plant surface. The resulting volume of droplets retained on the plant is $\eta_{0.5}$ = 85%. An injector nozzle provides the deposition of droplets less than 97 μm in size with $\eta_{0,5}$ = 4.4 %.

The utmost retention rate of the droplet deposition is a necessary condition for the efficient use of the working liquid and pesticide, while a sufficient condition is the pesticide penetration into the target plant and its toxic effect on the cells.

It is generally known that in an hour's time 1 m^2 of the lamina (the leaf blade) having the density of the stomata about 30,000 pores per cm^2 is capable to uptake from 3 to 4 liters of carbon dioxide (CO_2) from the surrounding air and to release the same amount of oxygen (O_2) into the atmosphere. The size of the ordinary air-stoma is 0.045 μm and that of the water-stoma is 0.0045 μm. The water molecule being 0.00015 μm in size can easily penetrate the plant leaf surface. The ability of a specific pesticide to penetrate a plant cell depends on the size of the pesticide molecules. The working fluid passes through the stomata (Figure 2) due to capillary suction at a pressure of $\Delta P_2 = \frac{2\sigma}{r}$, where *r* denotes the radius of the stomata, and also owing to the excess pressure of $\Delta P_1 = \frac{2\sigma}{R}$ inside the droplet, where *R* is the radius of the droplet surface. Having rebounded off the leaf, the droplet may leave a wet patch on the leaf surface, for which $R \to \infty$ and $\Delta P = 0$. The smaller the droplet, the greater the value of the excess pressure is; for example, in a drop of 20 μm, the pressure value is 0.014 MPa, while in a drop of 2 μm, this value reaches 0.14 MPa. Small-size droplets are more active. In difficult-to-wet plants, the stomata develop the resistance strength which is equivalent to the pesticide penetration force. From the point of view of efficacy of the pesticide penetration into the target plants, an important fact is that the ROsa centrifugal atomizer disintegrates the liquid water-insoluble active substance into the droplets ranging from 1 μm to 10 μm in size

Figure 5 illustrates the droplet of approximate ≈ 230 μm in size, which contains the droplets of emulsion (in a 1% concentration) dispersed therein, after the droplet has been deposited onto the hard surface. The smaller the droplets of the active substance, the more favorable conditions are created for the droplet penetration into the target plant or pest.

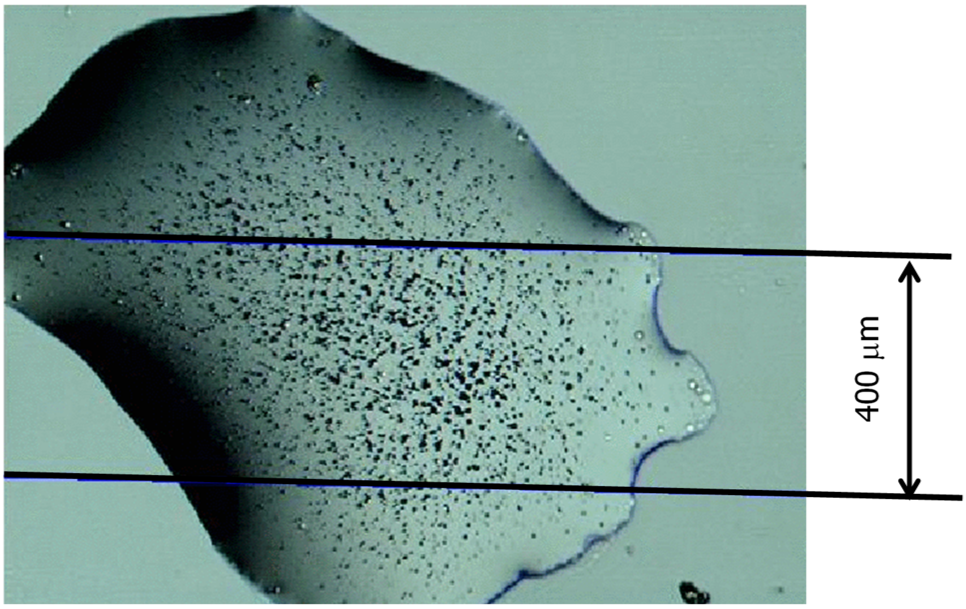


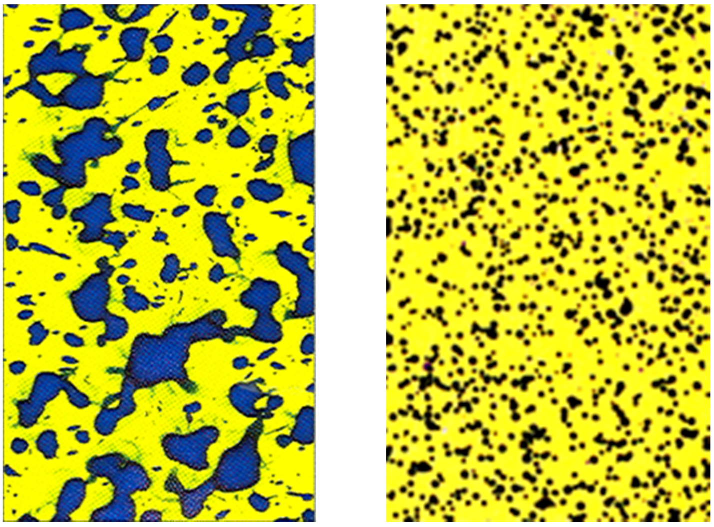
Figure 5. Emulsion dispersed in the droplet produced by the ROsa centrifugal atomizer

Due to the greater volume of droplets retained on the plant surface after spraying, the use of the ROsa centrifugal atomizer provides the possibility, with the same concentration of the active substance, to reduce, accordingly, the consumption rates of the working fluid and the pesticide as compared to the standard application rates for the pesticides recommended in the List of pesticides and agrochemicals permitted for use in Ukraine.

3. Optimal target coverage

In order to achieve the efficient coverage of the target plant surfaces, it is recommended [5] to perform spraying at the droplet deposit density between 20 and 30 droplets per cm^2 for pre-emergence herbicides, from 30 to 40 droplets/cm^2 for post-emergence herbicides, 30 droplets/cm^2 for insecticides, and from 40 to 70 droplets/cm^2 for fungicides. After 50-70 hours of operation, because of wear, the characteristics in a slit-type nozzle and an injector nozzle may drastically change, i.e., the liquid flow rate may increase by 10 per cent, the non-uniformity of the spray distribution along the sprayer boom length may become as high as 50 per cent, and the droplet size distribution deteriorates. Such instability of the spraying characteristics results in the excessive application of the working fluid, and the adequate quality of spraying is achieved by the way of abundant wetting the plants at the working fluid flow rates ranging from 200 L/ha to 300 L/ha (Figure 6).

The ROsa centrifugal atomizer performs dribble wetting and it ensures the droplet deposit density at a rate higher than 200 droplets per cm^2 and at the working fluid flow rate of 50 L/ha; for instance, in spraying post-harvest herbicides, the thickness of coverage with the droplets is five times greater than the recommended value. In the case with pre-emergence herbicides, when the entire field acreage is treated and the spray solution is immediately applied onto the soil surface, the flow rate of 25 L/ha is sufficient for the adequate coverage.



300 L/ha
with an
injector nozzle

50L/ha
with the ROsá
centrifugal atomizer

Figure. 6. Snapshots of the working liquid distribution
on the laboratory cards (magnified view)

The ROsá centrifugal atomizer ensures the stable characteristics in the spraying operations and it guarantees the retention rate of not less than 80% of the total volume of droplets of the dispersed fluid. This allows the introduction of the scientifically substantiated standards for the pesticide application rates that are based on the weight of the active substance and expressed, for example, in gram per cm^2, as the amount that is necessary for the extermination or suppression of the weeds.

In actual practice, <u>weather conditions</u> usually vary significantly from the optimal surrounding conditions recommended for spraying, which imply ambient air temperature below 25°C, relative humidity higher than 60 per cent and wind velocity less than 5 m/s [5]. Detrimental effects of inappropriate weather conditions during spraying may become apparent as a decreased volume of the retained droplets and an insufficient thickness of coverage. Therefore, the variability of the actual meteorological conditions must be taken into account while setting the standard rates for the pesticide applications. Changing the pressure, for example, from 0.2 MPa to 0.4 MPa results in a 40 % increase in the working liquid flow rate.

Wind may alter the shape of the nozzle spray pattern, it has its effect on the intended direction of the droplet travel and the droplet holdup time in the air, and wind also blows the droplets out of the spray pattern, and thereby, it adds up to waste of the working fluid because of evaporation. For instance, provided wind velocity is 9 m/s, the sprayer travel speed is 12 km/h, the ambient air temperature is 20°C, the working fluid temperature is 20°C, and relative humidity is 50%, with the use of the ROsa centrifugal sprayer, the droplets less than 52 μm in size evaporate entirely, whilst their share accounts for 2.7% in the total liquid volume being dispersed. The droplets of other size categories evaporate only partially due to water loss. Depending on a wind velocity value of 3 m/s, 7 m/s or 9 m/s, the volume of the evaporating working fluid amounts to 0.9 %, 4.5 % or 7.9 %, respectively.

When the value of relative humidity increases from 30 % to 60 %, provided the air temperature is 30° C and the wind velocity is 7 m/s, the evaporation decreases, accordingly, to 6%.

As it is advised in the relevant literature [5], slit-type nozzles are appropriate for spraying at the minimal sprayer speed of 4-5 km/h, while injector nozzles are better suited for the job at the sprayer speed of 7-8 km/h. When sprayer speed is within the range of 12 - 15 km/h, the efficacy of spraying drastically decreases; and at the sprayer speed of 30 km/h, when the opposing air stream is equivalent to a cross wind velocity of 8 m/s, the spraying operations are considered futile. The opposing air stream distorts the spray pattern in the slit-type nozzles. Therefore, with an aim to sustain the fluid distribution uniformity along the boom length of the self-propelled sprayers, the slit-type nozzles are spaced at a 0.35 m distance between them, but not at a 0.5 m distance.

The cone spray pattern in the Rosa centrifugal atomizer features the less aerodynamic resistance and the less droplet density, as well as the cone spray pattern is more steadfast than the flat spray pattern in the slit-type nozzle; moreover, the distribution of the retained droplets is essentially uniform along the whole length of the spray boom. Mathematical simulation of the droplet travel and their evaporation within the spray pattern of the Rosa centrifugal atomizer has shown that with an increase in the propulsion speed of the sprayer the percentage of water evaporated from the droplets reduces. With the idle sprayer, the liquid mass loss for evaporation in the droplet of 17 μm in size has been estimated as 50 per cent of the total droplet mass; while at the sprayer speed of 12 km/h and 30 km/h, the liquid mass loss has accounted for 30 % and 15 %, respectively. This can be explained as the consequences of an increase in the droplet absolute velocity and a shorter period of time for the droplet deposition. The efficacy of the spraying operations with the centrifugal nozzles at a propulsion speed of 30 km/h in the sprayer has been proved in practice. In contrast to the slit-type nozzles, the centrifugal nozzles are capable to perform the efficient spraying at high speeds, to save the time required for plant treatment and to cut the costs for chemical protection of plants.

With the use of the slit-type nozzles, in case the height or the horizontal position of the spray boom is changed by a value of 0.1 m according to the field relief profile, the pesticide application rate may be increased by 40 per cent [5].

The centrifugal nozzles, which atomize the spray liquid into very fine droplets and disperse them, are generally less sensitive to the changes in the position of the spray boom. At a distance of 0.5 m from the nozzle outlet, the spray pattern takes the shape of a cylinder and droplets are deposited perpendicular to the target surface. This is the reason why an alteration of 0.6 m ± 0.1 m in the position of the spray boom does not impair the uniformity of the spray fluid distribution. The spray boom is equipped with mechanical pitch locks that restrain the boom from extreme dislocations.

The droplet density of coverage and the greater volumes of the retained droplets that are attained with the ROsa centrifugal spray nozzles ensure the reliable spraying under a wide range of various environmental conditions, including those which are not optimal for the spraying operations.

CONCLUSION.

A six-fold reduction in the global pesticide pollution can be achieved due to the efficient and reliable spraying with the ROsá centrifugal atomizers, which produce the droplets less than 350 μm in size and perform the forced deposition of the droplets at a pressure of 0.3 MPa by the air stream induced into the cone spray pattern, and thereby ensuring a droplet retention rate of at least 80 per cent of the total droplet volume of the atomized liquid being sprayed onto the target plants.

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