The possibilities of droplet spectrum regulation at application of plant protection products

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ABSTRACT: Verification of the possibilities of a droplet spectrum regulation due to the change of working pressure, as well as the change of the size of the discharge orifice of a nozzle, was undertaken in laboratory conditions by measurement of the size of a droplet spectrum of the applied liquid. Selected types of low drift nozzles – Albuz AVI 025, Lechler ID 120, Lechler IDK 120-05, Lechler IDN 120-025, TurboDrop 03, Hardi INJET 02, Hardi B JET 02, Hardi LD 02 and a flat fan nozzle Hardi ISO F 02-110 – underwent the measurement. The measurement of droplet spectrum was carried out at the nozzle's working height of 500 mm, and at working pressures of 0.1, 0.2, 0.3, 0.5 and 0.7 MPa. A laser measure equipment was used to measure the droplet spectrum of liquid.

Keywords: low-drift nozzle; droplet spectrum; working pressure

Nowadays, the appliances for the application of pesticides are equipped with the latest electronics. Their operation is more or less the matter of computer technology. On the application frames of these appliances, where the dispersion of the liquid is occuring, nozzles are most often placed in holders of different kinds of design. Nozzles are small components that considerably influence the quality of application. A nozzle has three basic aims:

1. To disperse the applied liquid into droplets of a desirable size.
2. To follow exact dosage (flow capacity of the liquid) in a time unit.
3. To apply the liquid most evenly during the working purchase of the nozzle as well as of the entire appliance.

The quality of dispersion of liquid, the size spectrum of droplets, the possibilities of a droplet spectrum regulation etc., are factors, which the application technologies are concerned with. These technologies approach those factors in terms of quality of application, elimination of undesirable drift, security of the efficiency of applied active substances and, not at least place, the environment protection.

The most commonly used hydraulic dispersion makes mainly use of a hydraulic nozzle as a dispersing appliance. This nozzle forms droplets using pressure and the potential energy of the liquid. The construction of the hydraulic nozzle enables acceleration of liquid streaming, so that the liquid can be emptied as a membrane or a thread. The stream of the liquid extruding from the efflux nozzle disintegrates, due to turbulence and ambient air, into unstable formations with a large surface. Incidental defects of the thin membrane along with the surface tension lowers the surface area of the liquid fragmenting it into droplets (Trunečka 1996).

The hydraulic principle of dispersion is distinguished by its great variability of a droplet size. A part of small droplets does not have sufficiency of kinetic energy to achieve its point, therefore the energy is not sufficiently used, as the case may be, it becomes an undesirable element, which causes a drift of the applied liquid etc.

The creation of droplets is a complicated process that is influenced by many factors and that is not possible to view detachedly. Bengtsson (1961) divides these factors into 3 groups:

1. The construction of a nozzle, which defines the way the liquid leaves the nozzle.
2. The qualities of the liquid.
3. The qualities of the ambient air.

By the size of a droplet is meant a diameter of a globular droplet. The size of droplets is expressed by two values: NMD – (Number Median Diameter, so-called "weighted average", from the statistic point of view) and VMD – (Volume Median Diameter). More often practically used is especially VMD average, which is a critical indicator of the biological efficiency of a treatment. Because VMD makes provision for the dimension of droplets, it characterizes more precisely the quality and suitability of a droplet spectrum for each applied liquid.

To sum up, we can say that VMD correlates positively with the size of a nozzle, while it correlates negatively with the discharge angle (ARVIDSSON 1997). KOVAŘÍČEK (1997) agrees with this predication and suggests three general principles of the relation between the size of droplets and nozzles:

1. Nozzles with a wider angle of dispersion form smaller droplets.
2. Nozzles with a greater flowage form larger droplets.
3. The higher the pressure is, the smaller the droplets are.

Most common type of nozzles used for application with a surface sprayer is a flat fan nozzle. It works at the pressure from 0.1 to 0.5 MPa. Liquid is brought directly to the flat fan discharge orifice, which is shaped to create a flat discharge pattern. The size of the discharge angle affects not only the shape of the orifice but also the pressure of the liquid. It varies from 65° to 120°. An advantage of this type of nozzles is their simplicity and their ability of creating rather even dispersion of liquid at a relatively low pressure (LEFEBVRE 1993).

At the hydraulic nozzles the diagram of droplets changes at inverse proportionality with the changes of working pressure of applied liquid, as at RYBKA (2001). The proof of this relation, especially at low drift hydraulic nozzles, is a part of this thesis.

The main value determining the size of a droplet spectrum is the fractile D 0.5 that is named the median of the distribution function. It is indicated as VMD (Volume Median Diameter). It is a volume median diameter of droplets in the spectrum, to which it applies that the volume of all the droplets with a smaller diameter is equal to the volume of the droplets with a larger diameter. Other considerable parameters are border volume diameters D 0.1 and D 0.9. These show that 10% of the entire volume of droplets have a smaller diameter, while 90% have a larger diameter (FOLDYNA 1998).

Mathematical formulation of the width of the spectrum is neither simple nor definite; a several methods are used to formulate it. One option for this is the utilization of the VMD/NMD proportion. It is called the medial index and it takes the value 1 for a group of droplets of the same size and of values higher than 1 for size spectrum of droplets of different sizes.

MATERIALS AND METHODS

The aim of this thesis is the proof of the regulation of droplet spectrum of liquid depending on the changes of working pressure. Hydraulic flat fan low drift nozzles were selected to measure droplet spectrum.

The measurements were carried out in the laboratory of the Application Technology Group (ATG), the producer of application technique Hardi International A/S, in Denmark (Taastrup), during the years 2003 to 2005. The variety of values of working pressure – at which the nozzles were tested – was initially chosen as to apply the values of pressure recommended by the producer of the nozzles, as well as higher and lower values than those recommended.

Nozzles of both the same type and a comparable size were selected to collate the possibilities of the adjustment of a drift standard, in order to exclude the influence of the size and the shape of the discharge orifice. All of them equate to the size with a flow capacity of about 1.00 1/min, at the working pressure of 0.3 MPa. On the contrary, the influence of the size of the exit orifice on a standard of a drift was observed in two types of nozzles. However, the used nozzles were selected randomly of those available on Czech market, taking account of the most common type that is the so-called flat fan low drift nozzles.

The applied liquid used for the testing was pure water not including any adjuvant (surfactant etc.) that could affect physical properties of the liquid, e.g. a surface tension or viscosity. The effect of physical properties on liquid was not an object of this experiment.

The measurement of the size of created droplets was undertaken on a laser measure equipment called Aerometrics PDPA (Phase Doppler Particle Analyzer). The number of droplets used for the analysis always outreached the value of 10,000 items. Droplets were measured and then sorted in size intervals by 2 µm.

So-called Student's *t*-test was used to verify statistic cogency in groups of measured values. This test is especially used to confirm or disconfirm the zero hypothesis and the influence of the type of a nozzle as well as of the size of a discharge orifice on the size of created droplets.

So-called χ^2 test was used to verify the conformity of the groups of the measured values, especially for observation of dependence of the size of created droplets on the pressure of liquid at particular types of nozzles.

RESULTS

The effect of the change of the type of a nozzle on a droplet spectrum

The change of the structure of a droplet spectrum at standard Hardi ISO F 02-110 flat fan nozzles, Hardi LD 02 low-pressure nozzles and Hardi INJET 02 low drift nozzles with passive air-suction was monitored. Three referential working pressures were set: 0.1 MPa, 0.3 MPa and 0.7 MPa.

The findings of the measurement of the droplet size were – within the frame of the software of the laser equipment – sorted in size groups; basic calculations were then proceeded. The diagrams – Figs. 1 to 3 – show difference of cumulative frequency of the particular spectra on the working pressure of liquid.

Figs. 1 to 3 showes that proportion of small sized droplets are raising in dependence on the increasing working pressure. In case of low drift nozzle Hardi INJET is evident a raising elimination of small droplets on working pressure 0.3 MPa yet. However, all nozzles create high proportion of small droplets inclined to a drift on working pressure 0.7 MPa.

A group of values of Hardi ISO F 02-110 and Hardi INJET 02 nozzles was tested at working pressure of 0.1 MPa, using so-called Student's t-test at 0.95 probability level to compare the statistic relevancy of the differences in measured values.

$t = 15.2949$

$t_{0.95} = 1.64$, degrees of latitude number $\nu = n - 1 = 206$

$t > t_{0.95}$

The calculated critical value t is higher that the value $t_{0.95}$ for 206 degrees of latitude for the group of

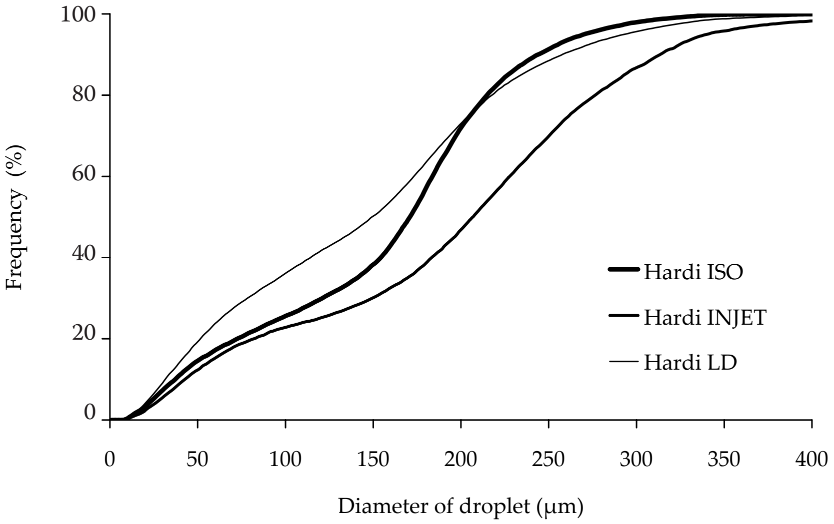

Fig. 1. Cumulative frequency on working pressure 0.1 MPa

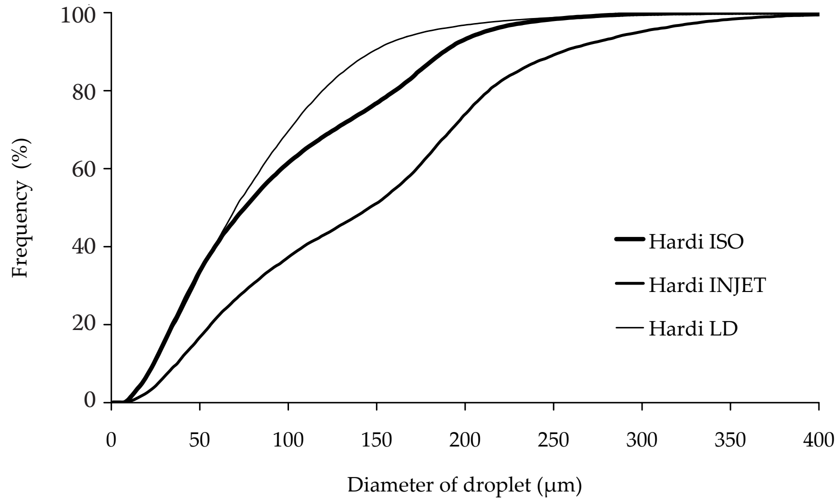

Fig. 2. Cumulative frequency on the working pressure 0.3 MPa

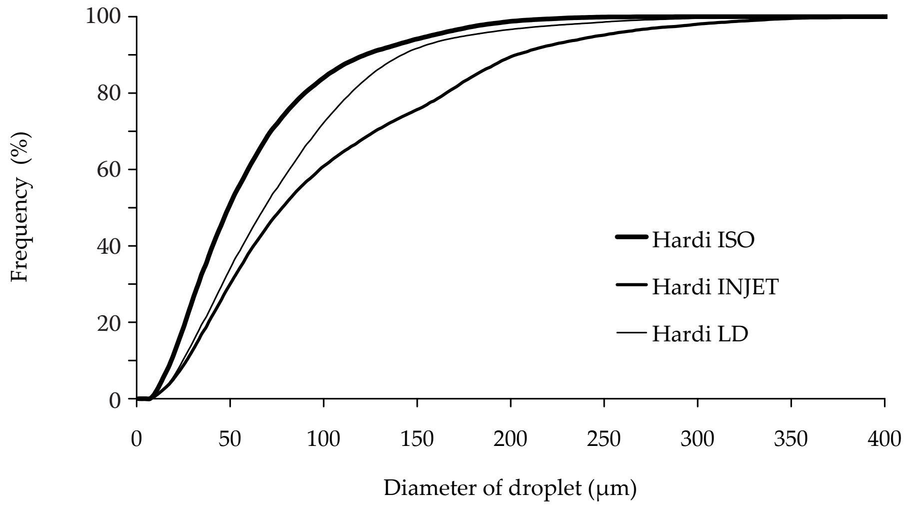

Fig. 3. Cumulative frequency on working pressure 0.7 MPa

values of cumulated frequency of droplets at Hardi ISO F 02-110 and Hardi INJET 02 nozzles at working pressure of 0.1 MPa; the difference between each group of values is statistically provable!

Statistic relevancy of differences in values measured at working pressure of 0.1 MPa at Hardi ISO F 02-110 and Hardi LD 02 nozzles was tested at the 0.95 probability level.

$t = 3.479936$

$t_{0.95} = 1.64$, degrees of latitude number $\nu = n - 1 = 206$

$t > t_{0.95}$

The calculated critical value t is higher that the value $t_{0.95}$ for 206 degrees of latitude for the group of values of cumulated frequency of droplets at Hardi ISO F 02-110 and Hardi INJET 02 nozzles at working pressure of 0.1 MPa; the difference between each group of values is statistically provable!

The effect of the change of pressure of liquid on a droplet spectrum

A formula of the dependence of VMD (1) – as a fundamental parameter determining the quality of liquid distribution – on working pressure of liquid for hydraulic nozzles, is presented in the introduction of this thesis, based on facts from studied literature. VMD, accordingly, correlates positively with the cube root of the value of working pres-

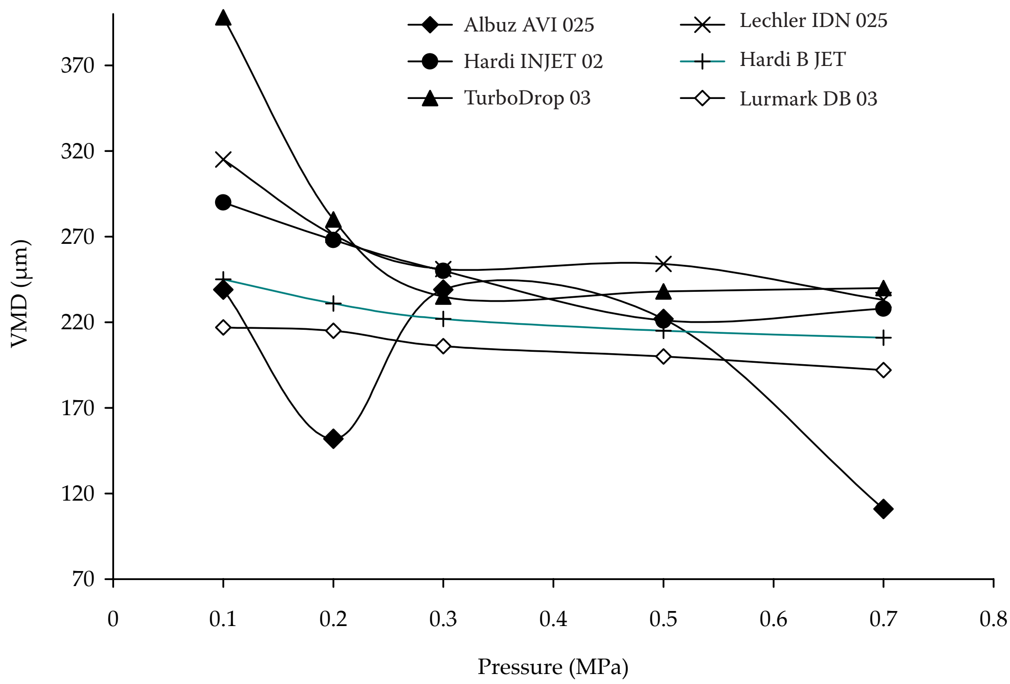

Fig. 4. Volume median diameter VMD according to measurement

Table 1. Measured values of VMD

Type of nozzle	1 0.1 MPa	2 0.2 MPa	3 0.3 MPa	4 0.5 MPa	5 0.7 MPa
Albuz AVI 025	239	239	222	152	111
Lechler IDN 025	315	271	251	254	233
Hardi INJET 02	290	268	250	221	228
Hardi B JET	245	231	222	215	211
TurboDrop 03	398	280	235	238	240
Lurmark DB 03	217	215	206	200	192

sure of liquid. This formula was generally verified for a standard flat fan nozzle. The object of the analysis of this thesis is to verify the relevance of the formula for low drift nozzles with passive air-suction. Following values of VMD at flat fan low drift nozzles (Table 1 and Fig. 4) were detected by a droplet spectrum analysis.

According to the verified formula (Rybka 2001)

$$\frac{\mathrm{VDM}_1}{\mathrm{VDM}_1} = \frac{\sqrt[3]{p_2}}{\sqrt[3]{p_1}} \qquad (1)$$

the table of VMD values (Table 2) and their diagram (Fig. 5) would look like following.

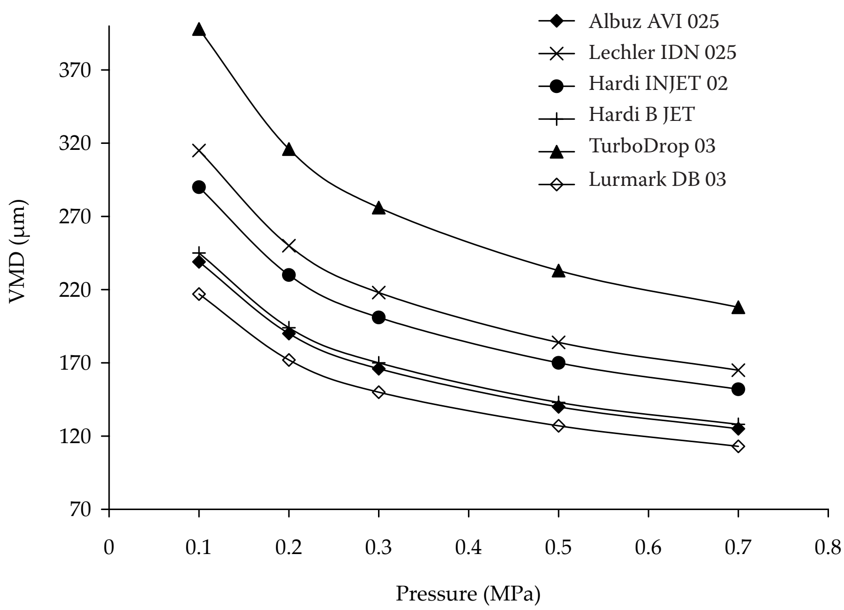

Fig. 5. Volume median diameter VMD according to theoretical calculation

Table 2. Expected values of VMD

Type of nozzle	1 0.1 MPa	2 0.2 MPa	3 0.3 MPa	4 0.5 MPa	5 0.7 MPa
Albuz AVI 025	239	190	166	140	125
Lechler IDN 025	315	250	218	184	165
Hardi INJET 02	290	230	201	170	152
Hardi B JET	245	194	170	143	128
TurboDrop 03	398	316	276	233	208
Lurmark DB 03	217	172	150	127	113

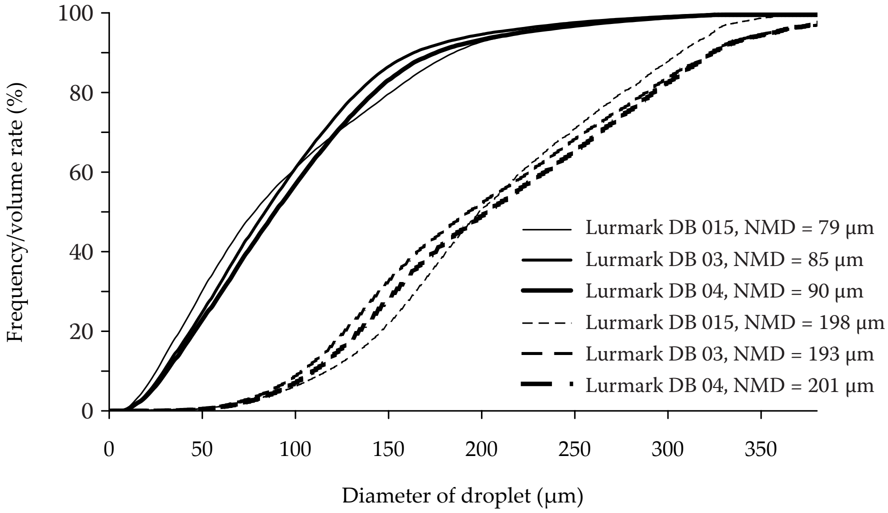

Fig. 6. Cumulative frequency and cumulative volume distribution on working pressure 0.7 MPa

Structural design of low drift nozzles expressively changes dependence of quality distribution on the working pressure, as showes diagrammatic comparison course of VMD value in dependence on the working pressure (Figs. 4 and 5).

It was verified by the test of χ^2 conformity, whether it is or it is not possible to use the verified formula determining dependence of VMD as an indicator of the quality of dispersion and of working pressure of liquid at low drift nozzles.

$\chi^2 = 372$

$\chi^2_{0.99}(20) = 37.6$

$\chi^2 > \chi^2_{0.99}$ (20 – degrees of latitude = $(r - 1) \times (s - 1)$)

At low-drift nozzles with passive air-suction I have to reject the zero hypothesis of the specified values of VMD corresponding with the theoretic values calculated according to the formula.

The effect of the changes of the size of the discharge orifice on a droplet spectrum

Low drift nozzles with passive air-suction were used again for detection of this potential effect. To this aim, they were the Lurmark DB 015, 03 and 04 nozzles. Droplet spectra were analyzed at the working pressure of 0.7 MPa.

Demonstrativeness of quality distribution in dependence of the size of orifice is negligible (pursuant to diagrammatic reference Figs. 6 to 8). Difference in droplet spectrum distribution in nozzle Lurmark DB 015 and nozzles Lurmark DB 03 and 04 is visible in Fig. 7, it showes numerical characteristics of dispersion.

A group of values of droplets frequency at Lurmark DB 03 and Lurmark DB 04 nozzles at working pressure of 0.7 MPa was tested by the so-called

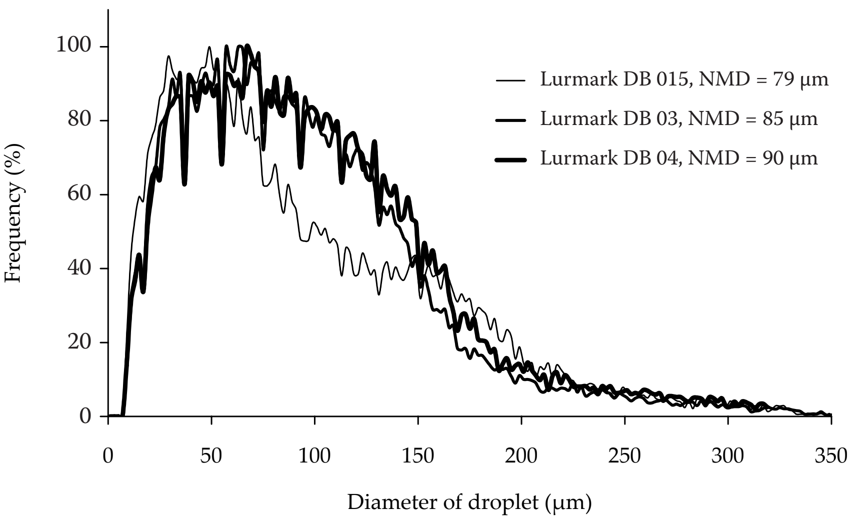

Fig. 7. Frequency of droplets on working pressure 0.7 MPa

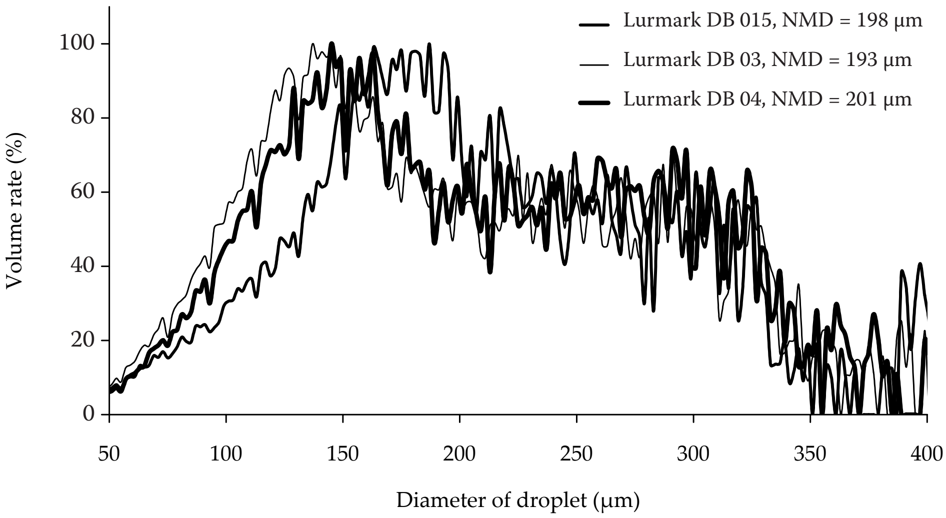

Fig. 8. Droplets volume distribution on working pressure 0.7 MPa

Student's test at 0.95 probability level to verify the relevancy of differences in measured values.

$t = 4.97731$

$t_{0.95} = 1.64$, degrees of latitude number $\nu = n - 1 = 183$

$t > t_{0.95}$

The calculated critical value t is higher than the value $t_{0..95}$ for 183 degrees of latitude for the group of values of frequency of droplets at Lurmark DB 03 and Lurmark DB 04 nozzles at the working pressure of 0.7 MPa, and the difference between the two groups of values is statistically provable.

Also statistic relevancy of differences of values of a normalized volume distribution at working pressure of 0.7 MPa at Lurmark DB 03 and Lurmark DB 04 nozzles was tested at 0.95 probability level.

$t = 0.12066$

$t_{0.95} = 1.64$, degrees of latitude number $\nu = n - 1 = 188$

$t < t_{0.95}$

The calculated critical value t is lower than the value $t_{0.95}$ for 188 degrees of latitude for the group of values of volume distribution of droplets at Lurmark DB 03 and Lurmark DB 04 at working pressure of 0.7 MPa, and the difference between the groups of values is not statistically provable.

DISCUSSION

The effect of the type of a nozzle on a droplet spectrum

The easiest solution is an exchange of nozzles, the change of the type of a nozzle, e.g. the use of some of many variations of low drift nozzles instead of the standard ones. The findings of this part imply a strong effect of using low drift nozzles, on elimination of small droplets; the higher the working pressure of liquid is, the stronger the effect is. Rather remarkable is a significant difference between particular types of low drift nozzles, even though coming from the same producer, as in case of Hardi INJET and Hardi LD. The assumption that by replacement of standard nozzles for the low drift ones we can always effectively prevent loss as well as a drift exposure to the environment – without the knowledge of the way they work – does not count generally. The proportion of small sized droplets inclined to a drift reduces considerably only with the use of higher working pressure. It is also possible to select more suitable types of low drift nozzles to assure better coverage of the target area, regarding the treated plant and the mode of action of the applied substance. From the tested nozzles I can strongly recommend Hardi INJET nozzle against Hardi LD nozzle for the use of contact pesticide at less favourable atmospheric conditions. Hardi INJET nozzle effectively eliminates the amount of small sized droplets at the whole rate of working pressure; even with the growth of pressure it forms droplets of rather medium size, in comparison with a standard nozzle.

The effect of the change of the pressure of liquid on a droplet spectrum

Another possibility of regulation of a droplet spectrum is a change of working pressure of liquid. It is the easiest form of the regulation of dispersion, although it has its bounds and rules. The automatic dosage regulation, which works on the principal of change of working pressure of applied liquid dependent on working speed, puts the possibility of the regulation of dispersion rather in the field of theory. The knowledge of dependence of working pressure and the standard of liquid dispersion on a droplet spectrum is fundamental in the field of the regulation of a droplet spectrum. The verification of dependence of the structure of a droplet spectrum on working pressure at low drift nozzles with passive air-suction is described in this section. The VMD value defines the standard of dispersion; according to the relation within standard flat fan nozzles, the dependence of VMD on working pressure of liquid is verified. There was no success in proving statistically the outright possibility to use the described inverse proportion of dependence of VMD change on the cube root of the change of working pressure, at low drift nozzles with passive air-suction. A limited set of data may have influence on this ascertainment; however, a more likely cause is the fact that the effect of the way and quantity of sucked air is not included in the original formula by an introduction of a constant.

The effect of the change of the size of the discharge orifice on a droplet spectrum

The last factor that can affect the structure of a droplet spectrum in operational conditions is the size of the discharge orifice of a nozzle. A simple change of the nozzle size affects dosage, such that it also brings a regulation of working pressure so that the flowage through the nozzle remains invariable. In practice two factors are merged to attain the reduction: an enlargement of the outflow nozzle and a synchronous reduction of working pressure. The effect of working pressure of liquid on the standard of dispersion is indisputable. The analysis of the last section deals with the extent of the nozzle size participation in the reduction. It is pursuable in practice to change the size of nozzles, observing the surface dosage, to the limit of the range of neighbouring sizes. Lurmark DB nozzles of the designated sizes 03 and 04 according to ISO norm were therefore selected to verify statistic relevancy of changes in measured values. Although the difference at 0.95 probability level appeared to be statistically provable at the testing of values of frequency of droplets in particular size rates, the statistic provability did not show to be at far more important values of volume division (effect on VMD). It can be presumed that the effect on the size of formed droplets is, within the context of the size of the exit orifice, minor, and negligible for the practice.

CONCLUSION

The results of statistic evaluation proved a strong effect of the utilization of low drift nozzles on the elimination of the creation of small sized droplet formations.

As far as the case of dependence of droplet spectrum structure on working pressure is concerned, there was no success in proving the described inverse proportion of dependence of VMD change on the cubic root of the change of working pressure for utilization at low drift passive air-suction nozzles. A limited set of data may have influence on this ascertainment; however, a more likely cause is the fact that the effect of the way and quantity of sucked air is not included in the original calculation formula by an introduction of a constant.

References

ARVIDSSON T., 1997. Spray Drift as Influenced by Meteorological and Technical Factors. [Doctoral Thesis.] Uppsala, Svedish University of Agricultural Science: 144.

BENGTSSON A., 1961. Der Einfluss der Tropfengrösse auf die Wirkung von Unkrautbekämpfungmitteln. Uppsala, Schriftenreihe des Instituts für Pflanzenbauen der Landwirtschaftlichen Hochschule: 99.

FOLDYNA A., 1998. Omezení úletu a pokryvnost u štěrbinových trysek. Mechanizace zemědělství, Speciál, *5*: 18–19.

KOVAŘÍČEK P., 1997. Plošné postřikovače pro ochranu rostlin a hnojení kapalnými hnojivy. Praha, Institut výchovy a vzdělávání MZe ČR: 38.

LEFEBVRE A.H., 1993. Droplet Production. In: MATTHEWS G.A., HISLOP E.C. (eds.), Application Technology for Crop Protection. Wallingford, Oxon, CAB International: 35–54.

RYBKA A., 2001. Teoretický rozbor dávkování a příčné nerovnoměrnosti aplikace u postřikovačů. In: Argotech Nitra 2001. Poľnohospodárska technika na začiatku 21. storočia. Zborník z medzinárodnej konferencie. Nitra, Slovenská poľnohospodárska univerzita v Nitre: 342–350.

TRUNEČKA K., 1996. Technika a metody v ochraně rostlin. Brno, Ediční středisko MZLU v Brně: 124.

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Možnosti regulace kapénkového spektra při aplikaci přípravků na ochranu rostlin

ABSTRAKT: Měřením velikosti kapénkového spektra aplikované kapaliny v laboratorních podmínkách bylo provedeno ověření možnosti regulace kapénkového spektra vlivem změny typu trysky, vlivem změny pracovního tlaku a vlivem změny velikosti výstupního otvoru trysky. Měření bylo provedeno pro vybrané typy trysek s protiúletovou úpravou Albuz AVI 025, Lechler ID 120, Lechler IDK 120-05, Lechler IDN 120-025, TurboDrop 03, Hardi INJET 02, Hardi B JET 02, Hardi LD 02 a štěrbinovou tryskou Hardi ISO F 02-110. Měření kapénkového spektra probíhalo při pracovní výšce trysky 500 mm, při pracovních tlacích 0,1; 0,2; 0,3; 0,5 a 0,7 MPa. K měření kapénkového spektra kapaliny bylo použito laserové měřicí zařízení.

Klíčová slova: nízkoúletová tryska; kapénkové spektrum; pracovní tlak

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