DE GRUYTER
OPEN
DOI: 10.1515/agriceng-2016-0031

ISNN 2083-1587; e-ISNN 2449-5999
2016,Vol. 20,No.2, pp.101-108
Agricultural Engineering
www.wir.ptir.org

THE CHANGE IN SPECTRUM OF DROPS IN THE EXPLOITATION PROCESS OF AGRICULTURAL NOZZLES

Alaa Kamel Subr[a,b*], Józef Sawa[a], Stanisław Parafiniuk[a]

[a] Department of Machinery Exploitation and Management of Production Processes, University of Life Sciences in Lublin,
[b] Department of Agricultural Machines and Equipment, College of Agriculture, University of Baghdad, Baghdad, Iraq
[*] *Corresponding author e-mail :alaa.subr@up.lublin.pl*

ARTICLE INFO

Article history:
Received: December 2015
Received in the revised form: January 2016
Accepted: February 2016

Key words:
agricultural nozzles
spectrum of drops
volume median diameter;
nozzles wear
spray pressure

ABSTRACT

Agricultural nozzles usually produce a different drops size depending on the pressure and the physical condition (work life) of the nozzle besides producing a wide range of the drops spectrum in the spray cloud. In this paper the standard flat fan nozzles were investigated regarding the effect of the working pressure and the nozzle physical condition (new and worn nozzles). The size of drops and the spectrum of drops across the long axis of the spray pattern were examined by using Sympatec GmbH Laser Diffraction. Reducing the working pressure from 3 to 2 and then to 1 caused production of larger drops, also using worn nozzles (especially with lower pressure) changed the drops size which is expected to be produced from the new nozzles. The standard flat fan nozzles produced a wide range of the drops spectrum inside the spray cloud, generally small drops (less than 150 µm) concentrated in the middle of the spray pattern while the big drops (250-350µm) were situated on the edge positions (70 cm from the centerline) of the spray pattern.

Introduction

Agricultural pests are organisms which decrease the availability, quality or value of agricultural products. It may be an insect, weed, disease or animal. This pest is usually controlled by pesticides which unfortunately also contribute to serious environmental and health problems for human, animal and their food. But at the same time giving up control of the agricultural pests will result in a big loss in yield (about one fifth of the total crop production). The spray nozzle controls the amount of the applied pesticide as it forms the spray pattern, breaks the mix into droplets and propels them in the proper direction, also determines the uniformity and the coverage of the spray (Klein et al., 2011).

Agricultural nozzles made of different materials (brass; plastic; stainless steel; ceramic; etc.) and each material has work life different than the others. The size or the dimensions of the nozzle tip are classified according to the ISO 10625 (2005) depending on the flow rate of the nozzles under certain pressure, each nozzle was given a certain color according to its size. Agricultural nozzles are also available with a different spray angles (65º; 80º; 110º; etc.), and a different design (twin jet, air induction; pre-orifice; etc.).

There are different types of nozzles according to the drops size, the BCPC (British Crop Protection Conference) classification of nozzles was set in 1985; it was based on the drops size and it divided the quality of spray produced by hydraulic nozzles into the following five categories: very fine; fine; medium; coarse and very coarse (Doble et al., 1985). The another classification set by ASAE S572 in 2004 added one more category to the previous classification, the ASAE S572.1 in 2009 defined the droplet spectrum categories for the classification of spray nozzles, relative to specified reference fan nozzles discharging spray into static air and classified the nozzles according to drops size to eight categories.

The ASAE S572.1 mentioned that measuring the droplet size distributions is an important reason for assessment of the performance of a particular nozzle, and by using small droplets the good and uniform coverage of the target is usually best achieved while larger droplets tend to retain their momentum for longer and, therefore, they are less prone to interact with cross winds which can cause spray drift.

Dv0.5 or Volume Median Diameter (VMD) is the droplet diameter when 50% of the spray volume is contained in droplets of a lesser diameter, while the proportion of the spray volume 10% and 90% contained in droplets of the specified size or less are called Dv0.1 and Dv0.9 respectively. The Relative Span is a dimensionless measure of the drops sizes which were spread in the spray (Vallet and Tinet, 2013).

Increasing the pressure for different types of nozzles from 3.0 to 5.0 bar reduced the VMD for conventional nozzles by approximately 9% and increased the volume percentage of drops smaller than 100 μm in diameter by 48%; the measurement results showed that the nozzle performance was a function of a design, operating pressure and spray liquid properties (Miller et al., 2008).

The drops size could be measured in the lab by using a laser based on the spatial or flux technique. There are many drop size analyzers available; most of them use optical methods (typically non-intrusive and do not influence the spray behavior during testing) to characterize sprays which fall into two main categories: imaging and non-imaging. The first one includes photography and holography. Non-imaging methods can be subdivided into two classes, those that measure a large number of drops simultaneously (ensemble) and those that count and size individual drops one at a time (single particle counters) (Schick, 2006).

Apart from the material the nozzles are made of, values of the volume median diameter (VMD) with the nominal flow rate of 0.75 l/min were found generally lower in the stream center for new and worn nozzles, and values of VMD of all other new and worn nozzles with the nominal flow rate of 1.6, 2.2 and 3.0 l/min decreased starting from the stream center and began to increase at about ± 20 cm from the stream center (Duvnjak et al., 1998).

New and worn nozzles with a 0.8 l/min flow rate haveDv0.5 for spray drops smaller generally at the center of the spray pattern or spectra. The droplet size of the new nozzles which are made of different materials, but with the same flow rate was approximately the same (Ozkan et al., 1992).

The objective of the study

The importance of studying the drops size spectrum is to know the percentage of small drops, which is responsible for the spray drift, even though it produces better coverage especially if the type of the pesticide requires this (insecticide for example). On the other hand, the big drops reduce the chance of a drift occurring although it is responsible for the pesticide run-off (bounce from target). The drops size is important also to determine the application rate since big drops spray application requires a higher application rate. Therefore, the objectives of the study are as follows:

1. The analysis of the spectrum of drops for standard flat fan nozzles concerning the uniformity of the spray cloud for new and worn nozzles.
2. Investigation of the trend of the drops diameter changing alongside of the spray cloud.

Materials and methods

The change in the nozzle tip dimensions due to its work hours (nozzle wear) could affect the produced drops size, therefore, it may alter the nozzle drop size category, for example, from fine spray to medium spray. Unfortunately, this change in the drops size and the nozzle wear progress is difficult to observe with an unaided eye.

Standard flat fan nozzles (TeeJet XR 110/03 VP Spraying Systems Co.) with the nominal flow rate 1.18 l/min and with a medium/fine drops size was investigated in the test, 24 nozzles were numbered (12 nozzles new and 12 nozzles to be damged) and used in the test.The drops sizes were measured for all the nozzles with the Sympatec GmbH (Clausthal-Zellerfeld, Germany) Laser Diffraction device which uses HELOS/R system with a measuring range from R1 to R8 (0.1-8.750 μm).The measurements were taken 50 cm under the nozzle orifice at 1.2 and 3 bar pressure and with three repetitions in the centerline and in seven positions to the left hand side (L10-L70) and the same for the right hand side (R10-R70) of the spray centerline (15 positions across the long axis of the spray pattern), the distance between each two positions was 10 cm. All nozzles were subjected to 10 hours of warm-up with water only in the wear tank (1000 l tank had 5 pipes in the upper side, every pipe held six nozzles) and then drops sizes were measured again and were considered to be the data for the new nozzles or nozzles before the wear process simulation (accelerated wear process).

After that, 12 nozzles were chosen (with numbers from 1-12) and subjected to the accelerated wear process with the mixture of water and wear agent (Kaolin KOM 18.2 kg mixed with 300 l of water) for 100 hours with 4 bar pressure; the drops size measurement was done after this process and considered to be the data for worn nozzles.

Figure (1) shows the laser measurement setting and instructions from ASAE S572.1 for drops size measurement; the acquired data were the drops size in Microns (VMD) and the cumulative volume percentage of drops size ranges: $\leq$150 μm; 150-250 μm; 250-350; μm and $\geq$ 350 μm.

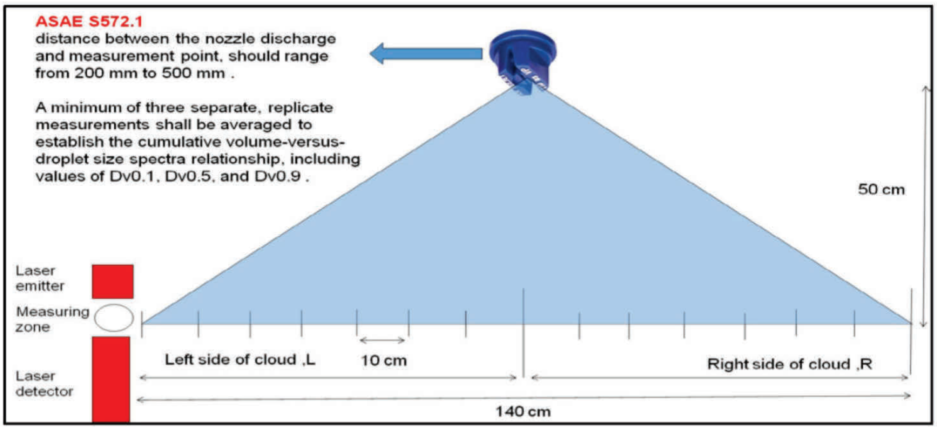

Figure. 1. Schematic diagram for the laser measurement setting

Results

Reducing pressure from 3 to 2 and then to 1 bar (Fig. 2) for the worn nozzles influenced on the drops size (VMD) across the long axis of the spray pattern and produced bigger drops (higher VMD). In the same figure we can also see that the VMD for the new nozzles was slightly smaller than for worn nozzles under 3 bar pressure. Worn nozzles produced a higher flow rate than new nozzles (Subr et al., 2015) which requires reducing the pressure to compensate this difference in the flow rate (in the case the operator is not planning to change his nozzles for economic reasons, for example). Unfortunately, this action will change the drops size also (as was mentioned before) which in turn will probably affect the biological efficacy of the pesticide application process.

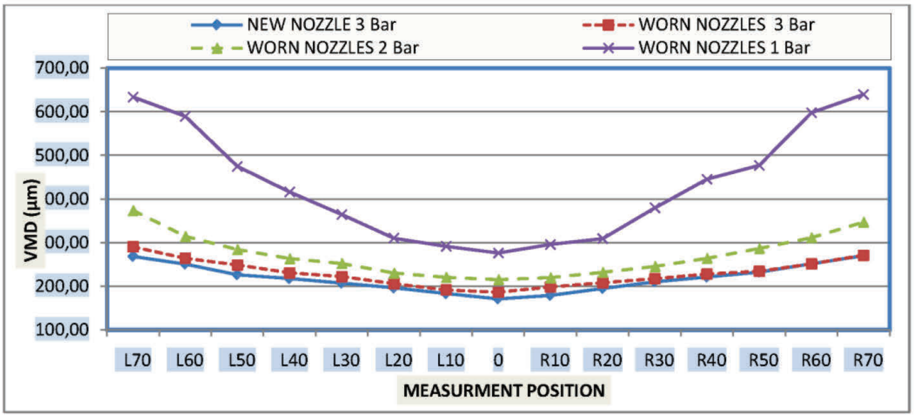

Figure 2. Droplet size (VMD) for new and worn nozzles with different pressure. Measurement positions: 0=centerline of spray spectrum; L,R=distance to the left and right side of centerline respectively, (cm)

The cumulative volume percentages (Fig. 3 and 4) for drops size ranges across the spray pattern for the new and worn nozzles with three bar pressure are diverse.The drops with size less than 150 μm were present in higher share in the zero position than in further positions (L70 and R70) while the drops size ranges 250-350 μm and ≥ 350 μm showed a reverse trend for the new and worn nozzles.

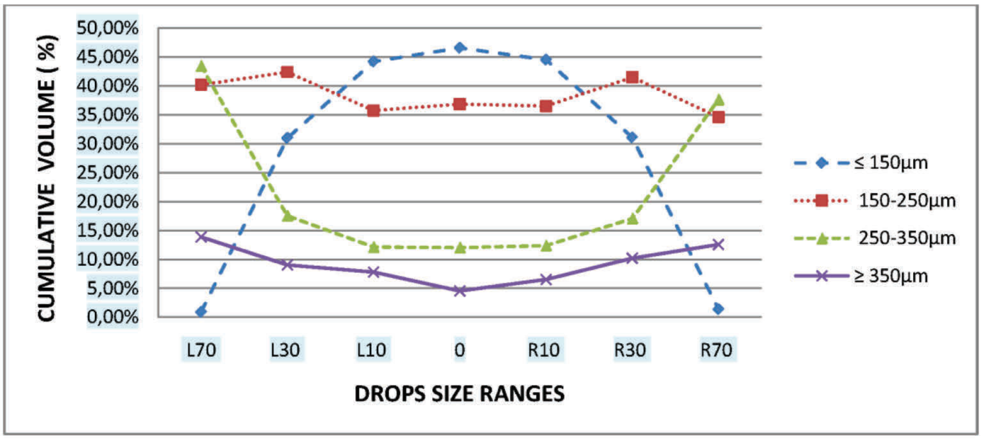

Figure. 3. The cumulative volume percentages for drops size ranges for the new nozzles with 3 bar pressure

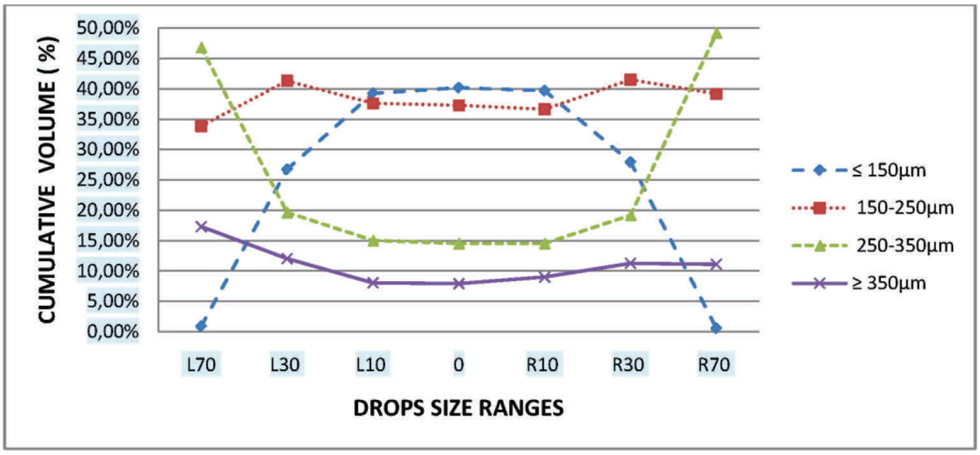

Figure. 4. The cumulative volume percentages for drops size ranges for the worn nozzles with 3 bar pressure

The comparison between the right hand and left hand side of the spray pattern for new and the worn nozzles with three bar pressure (Fig.5 and 6) shows that the right hand and left hand side were almost the same for all the drops size ranges and in all positions except the edge one (70 cm to the right hand and left hand side) which was different only for the drops size ranges 150-250 µm and 250-350 µm for the new nozzles and for the drops size ranges 150-250 µm, 250-350 and ≥350 for the worn nozzles.

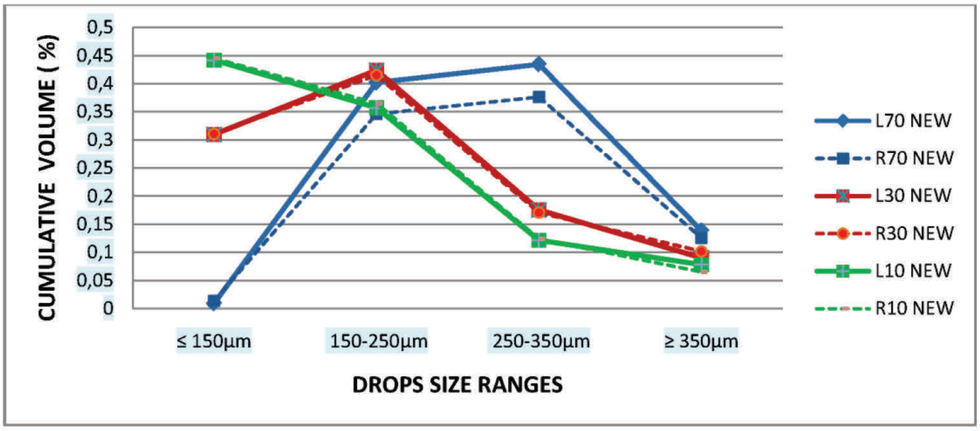

Figure. 5. Comparison between the right hand and left hand side of the spray pattern for new nozzles

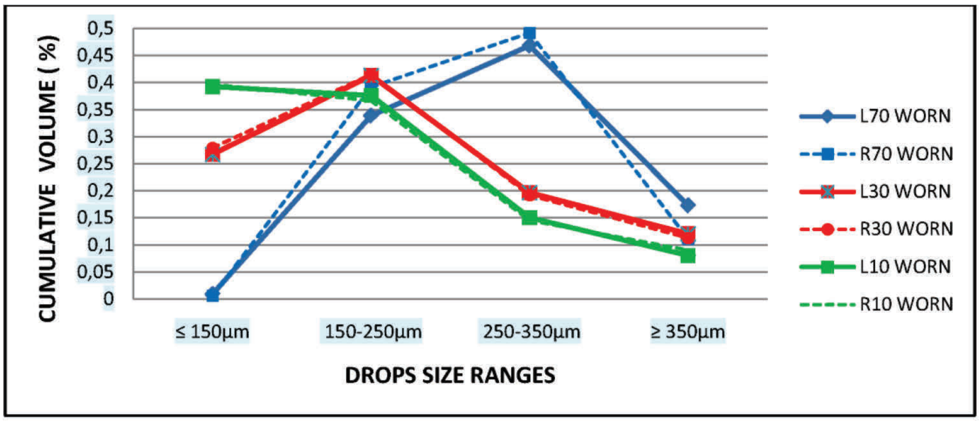

Figure.6. Comparison between the right hand and left hand side of the spray pattern for worn nozzles

The cumulative volume percentage of the drops size ranges (Fig. 7) for new and worn nozzles on the left hand side of the spray pattern (the right hand side was almost the same like the left hand side) shows that the new nozzles produced a bigger percentage of the drops size under 150 µm in positions L30 and centerline of the spray spectrum, whilst the worn nozzles gave the biggest percentage of 250-350 µm and ≥ 350 µm drops in all positions of the spray spectrum.

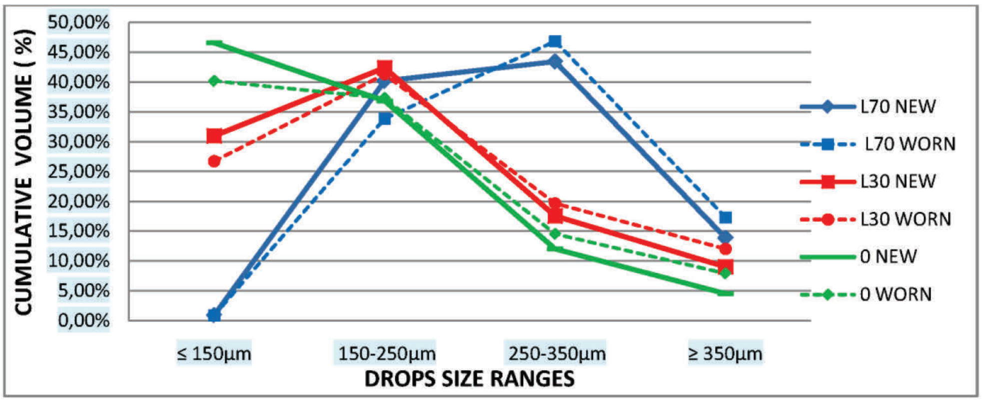

Figure. 7. The cumulative volume percentage of the drops size ranges on the left side of the spray pattern spectrum for new and worn nozzles with 3 bar pressure

These diversity of drops sizes alongside the spray pattern may be reduced when using spray overlapping (three nozzles interfere to produce one pattern) which means that the higher percentage of big drops in the edge position will be mixed with a higher percentage of small drops in the centerline to produce a more homogeneous pattern.

Conclusion

1. The standard flat fan nozzles produced a different drops size alongside the spray pattern, the small size drops concentrated in the middle of the spray pattern while the biggest drops were present on the edge.
2. There was not a big difference in the drops size between the right hand and left hand side of the spray pattern.
3. The worn nozzles produced bigger drops than the new nozzles in almost all measurement positions.
4. The cumulative volume percentage for the drops size range (≤150 µm) was observed in higher value in the centre and 30 cm position than at the edge position (70 cm from centre), while the 250-350 µm range drops were observed in higher amounts in the edge position than in the centre or 30 cm positions. The drops of 150-250 µm range were present in almost the same share in all positions.

References

ASAE S572. (2004). Spray nozzle classification by droplet spectra. *American Society of Agricultural Engineers.*

ASAE S572.1. (2009). Spray Nozzle Classification by Droplet Spectra. *American Society of Agricultural Engineers.*

Doble, S.J., Matthews G A, Rutherford I, Southcombe E S E. (1985). A system for classifying hydraulic nozzles and other atomisers into categories of spray quality.*Proceedings for British Crop Protection Council Conference.*1125-1133.

DuvnjakV., Banaj D., Zimmer R., Guberac V. (1998). Influence of nozzle wear on flow rate and stream droplets size. Die Bodenkultur, 49(3): 189-192.

ISO 10625. (2005). International Standard.Equipment for crop protection – Sprayer nozzles – Colour coding for identification. 2005. 4 p.

Klein R.N., Jeffrey A. Golus and Greg R. Kruger (2011). Evaluation of Soybean (Glycine max) Canopy Penetration with Several Nozzle Types and Pressures, Fungicides - Beneficial and Harmful Aspects, Dr. Nooruddin Thajuddin (Ed.), ISBN: 978-953-307-451-1, InTech, DOI: 10.5772/27609. Available from: http://www.intechopen.com/books/fungicides-beneficial-and-harmful-aspects/evaluation-of-soybean-glycine-max-canopy-penetration-with-several-nozzle-types-and-pressures

Miller, P.C.H., Tuck, C.R., Murphy, S., and Ferreira, M. (2008).Measurement of the droplet velocities in sprays produced by different designs of agricultural spray nozzle.Paper ID ILASS08-8-5, 22nd ILASS-Europe, 8-10 September 2008, Como Lake, Italy.

Ozkan H.E., Reichard D.L., Sweeney J.S. (1992). Droplet size distributions across the fan patterns of new and worn nozzles.*Transaction of the ASAE, 35(4)*, 1097–1102.

Schick, R.J. (2006). Spray Technology Reference Guide: Understanding Drop Size *Spraying Systems Co.*

Subr, A.K., Sawa, J., & Parafiniuk, S. (2015). Practical Deviation in Sustainable Pesticide Application Process. Agriculture and Agricultural Science Procedia, 7, 241-248. http://doi.org/10.1016/j.aaspro.2015.12.037

Vallet, A. and Tinet, C. (2013). Characteristics of droplets from single and twin jet air induction nozzles: a preliminary investigation. *Crop Protection*, 48: 63-68.

ZMIANA SPEKTRUM KROPLI W PROCESIE EKSPLOATACJI ROZPYLACZY ROLNICZYCH

Streszczenie. Oprócz generowania szerokiego wachlarza spektrum kropki w chmurze cieczy rozpylacze rolnicze zazwyczaj generują krople w różnych rozmiarach w zależności od ciśnienia i warunków fizycznych rozpylacza. Niniejszy artykuł bada standardowe rozpylacze płasko-strumieniowe w odniesieniu do wpływu ciśnienia roboczego i warunków fizycznych rozpylacza (nowe i zużyte rozpylacze). Rozmiar kropli oraz spektrum kropli wzdłuż osi wzdłużnej wzoru cieczy badano za pomocą urządzenia do dyfrakcji laserowej Sympatec GmbH Laser Diffraction. Obniżenie ciśnienia roboczego z 3 na 2, a następnie do 1 bar spowodowało powstanie większych kropli. Ponadto zastosowanie zużytych rozpylaczy (szczególnie przy niższym ciśnieniu) zmieniło rozmiar kropli, które miały powstać w przypadku nowych rozpylaczy. Rozpylacze płasko-strumieniowe wygenerowały szeroki wachlarz spektrum kropli wewnątrz chmury cieczy. Generalnie, małe krople (mniejsze niż 150 μm) koncentrowały się wewnątrz rozpylanego strumienia podczas, gdy duże krople (250-350 μm) znajdowały się na jego bokach (70 cm od linii środkowej).

Słowa kluczowe: rozpylacze rolnicze, spektrum