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Laboratory Investigation of Nozzle Type, Size and Pressure Effects on Spray Distribution

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ABSTRACT

The current study attempts to experimentally determine the effects of nozzle type, size and pressure on spray parameters. A total of 8 even flat fan nozzles were tested at pressures of 2 and 3bar. Spraying pattern analyzing method (pattrenator) was used to measure spray width and distribution. Liquid volume under the nozzle from pattrenator was quantified by weight method using precision electrical balance. The results indicated that DG flat fan nozzle behaviour was to some extent similar to that TP flat fan nozzle but additional variables like increase of spray width. Results also showed that small variations in nozzle pressure can cause significant difference in spray width and spray distribution. The current work presents liquid volume data under the nozzle centre increased with increasing nozzle size.

1. Introduction

The use of conventional broadcasting sprayers in the agricultural fields raises a lot of problems. A huge amount of chemicals is lost between planting rows. Plant protection products (ppp) are dangerous chemicals and must be applied with the utmost efficiency to prevent environmental pollution and save costs [1]. According to the ASABE standard, to reduce agrochemicals losses between rows in the field, band boom spraying is used instead of broadcast boom spraying. This technology works on the basis one nozzle for every line and it suitable to the size of the band or row. In addition, spaces between rows are not sprayed, which saves significant farming cost by reducing chemical wastage and off-target environmental pollution [2].

The proper amount of chemicals applied uniformly from the spray nozzle to the crop or soil surface is one of the successful spray application requirements. Thus, maintaining accurate and uniform spray pattern is critical to proper application, If operators understood how factors influenced spray uniformity [3].

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Environmental concerns and rising demands for optimizing agrochemical application by spraying system are increased. The continuous growth and change in the size of plant require an accurate adjustment of the spray width; therefore, different spray nozzles types and sizes have been used to control spray width and distribution to improve performance of sprayer [4-6].

Accurate application of sprays is important to minimize dangerous impacts from chemicals. Agricultural nozzles are designed to obtain certain specific spray width to accurately apply agrochemicals to the crop canopy, targeted weeds, or soil surface. Numerous procedures are used to determine the effect of nozzle type on spray width and distribution. Pre-orifice nozzle or drift guard even flat fan nozzle (DG) was developed and manufactured by Delavan-Delta, Inc. to work for as a single nozzle over the rows of the plants [7] and to produce uniform spray distribution [6]. One of the most important factor affect spray distribution is nozzle pressure. Increasing of the pressure tend to improve the uniformity of spray distribution [9, 10].

Spray pattern width for band spraying can be defined as the effective sprayed width by a single nozzle, and spray width is the band width [2]. According to static spray distribution test, the nozzle settings could not be simply calculated. There are deviations between the theoretically calculated spray width and the actual width [11].

Spray volumetric distribution is one of the most important indicators of the nozzle performance [12]. An even spray distribution is obtained by selecting and calibrating of the nozzles correctly [13] using spray analysing system or patternator [14]. The aim of this study is to know effects of nozzle type, size and pressure on spray parameters in banding spraying application.

2. Materials and methods

2.1 Selection Nozzles

Four even drift guard DG flat-fan nozzles and four even TeeJet TP flat-fan nozzles were used for this study. These nozzles were manufactured by spraying systems co, Inc. Wheaton, Illinois, USA. Nozzle sizes were classified according to the International Organization for Standardization (ISO) of 015, 02, 03 and 04 (0.15, 0.2, 0.3, 0.4 gpm) and comprise of the BCPC threshold nozzles [15]. The nozzles were chosen because of their common using in banding spraying application.

2.2 Flow Rate Test

The discharge rate tests of the nozzles (L/min) were conducted in the aeronautics laboratory of the faculty of mechanical engineering, university technology, Malaysia by collecting amount of water directly from the nozzle on a container at a system pressure of 2 and 3 bar for 1 minute. A precision electric balance was used to measure the nozzle output. The spray liquid used was tap water. A 140 L pressurized bottle was used to supply water discharged from the nozzle tip. The system pressure was adjusted via a pressure regulator. The tests of discharge rate were repeated three times and the maximum deviation of all nozzles with the nominal flow rate was ± 2.5%. Flow rate of the spray nozzles selected are shown in Table 1.

Table 1
Flow rate for different DG and TP even flat fan nozzles at pressures of 2 and 3 bar

Nozzle type	Nozzle code	Nominal flow rate (L/min)	
		2 bar	3 bar
Drift guard	DG95015E	0.48	0.59
TeeJet	TP95015E	0.48	0.59
Drift guard	DG9502E	0.65	0.79
TeeJet	TP9502E	0.65	0.79
Drift guard	DG9503E	0.96	1.18
TeeJet	TP9503E	0.96	1.18
Drift guard	DG9504E	1.29	1.58
TeeJet	TP9504E	1.29	1.58

2.3 Spray Pattern Width Test

Spray width of the nozzle was presented as the distance between two spray ends at spray height of 0.50m above the patternator. The measurements were repeated three times. Results of the spray width were presented as (m) [16].

2.4 Static Spray Volumetric Distribution Test

Spray volumetric distribution of the nozzle was determined under laboratory conditions using a spray pattern analysing system or patternator [14, 17, 18]. The patternator was manufactured in the workshop with dimensions 300 cm length × 100 cm width spray table with fifty V-shaped gutters (6 cm width × 3 cm depth). The patternator was inclined 6° from the horizontal plane [16, 19] as shown in Figure 1. Single nozzle was placed 0.50 m above the centre of the patternator. System pressure was set at 2 and 3 bar. A set of plastic tubes (250 mL) was used in front of the table to collect the spray liquid from each channel. A precision electric balance was used to determine the transversal volumetric distributions collected during 1 min. Results of the liquid volumetric distribution were presented as (mL/min). All tests were carried out at average 30C° and 79% RH. Nozzle type, size and pressure combinations were selected randomly.

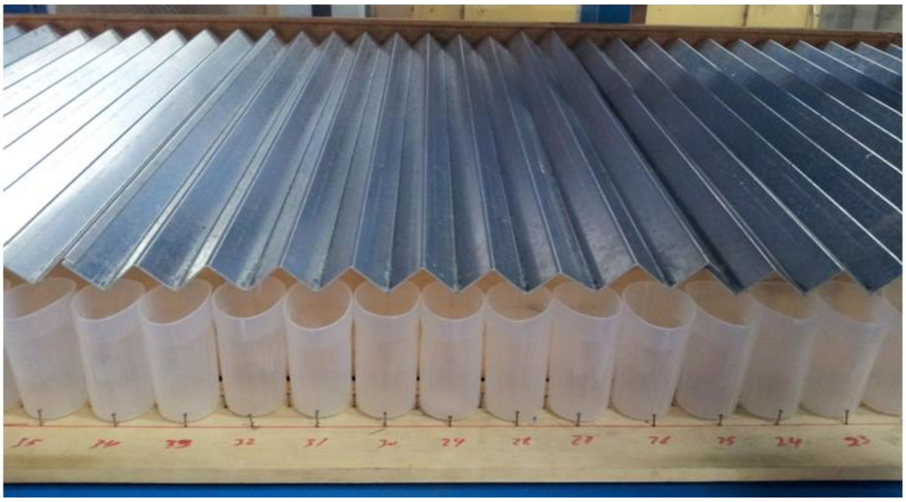

Fig. 1. Spraying pattern analysing system (pattrenator)

3. Results and Discussion
3.1 Spray Pattern Width

The results in Table 2 can help determine how the system pressure should be used to get specific spray width of the nozzle. In general, DG nozzle gave spray width bigger than TP nozzle. There was no significant effect for the nozzle size on spray width. Increasing the system pressure increased the spray width of the nozzles.

Table 2
Average spray pattern width for different DG and TP nozzles at pressures of 2 and 3 bar

Nozzle type	Nozzle code	Average spray pattern width(m)	
		2 bar	3 bar
Drift guard	DG95015E	1.30	1.43
TeeJet	TP95015E	1.00	1.09
Drift guard	DG9502E	1.30	1.43
TeeJet	TP9502E	1.00	1.09
Drift guard	DG9503E	1.30	1.43
TeeJet	TP9503E	1.06	1.09
Drift guard	DG9504E	1.31	1.44
TeeJet	TP9504E	1.06	1.09

3.2 Static Spray Volumetric Distribution

The uniform of spray distribution is one of the banding spraying requirements. According to the spray results, nozzle type affects significantly on the spray distribution. A standard TP flat fan nozzle achieved the best spray distribution in comparison to the DG nozzle. TP nozzle gave a consistent deposit across the spray width by reducing the difference in the heights of the peaks under the nozzle centre and the neighbouring peaks around near to the spray edges as illustrated in Figure 2.

From Figure 3, it can be noticed that the use of bigger nozzle sizes increases the liquid volume under the nozzle centre. The results in Figure 4 show that increasing the system pressure increases the liquid volume under the nozzle centre and improves the spray distribution because of reducing the differences in the heights of the peaks under the nozzle centre.

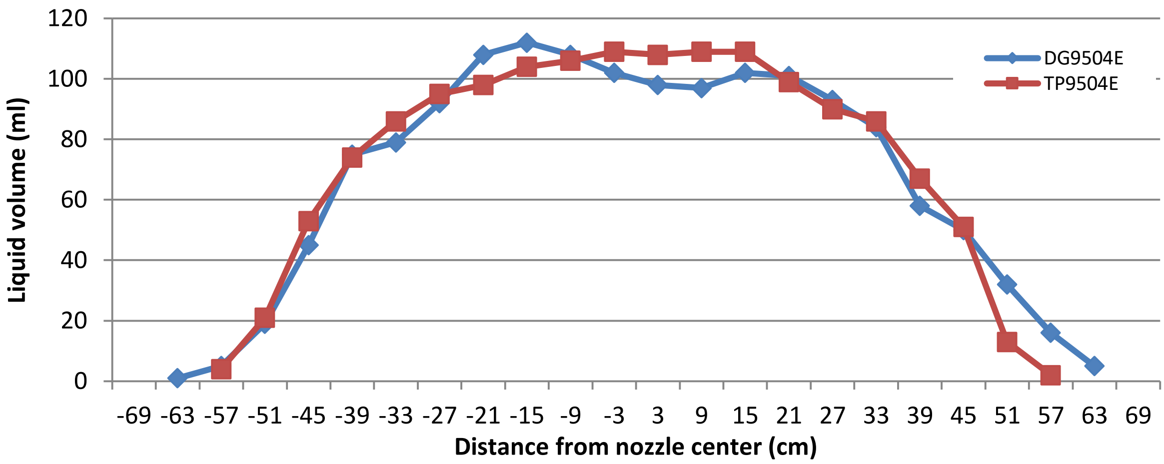

Fig. 2. Spray volumetric distribution of TP and DG nozzles at a pressure of 3 bar

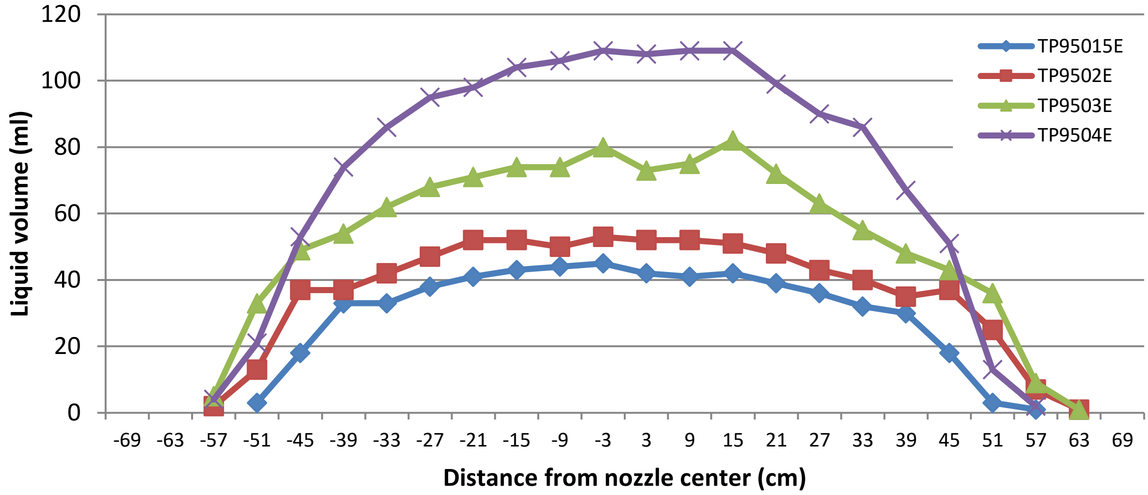

Fig. 3. Spray volumetric distribution of TP nozzle sizes 015, 02, and 03 at a pressure of 3 bar

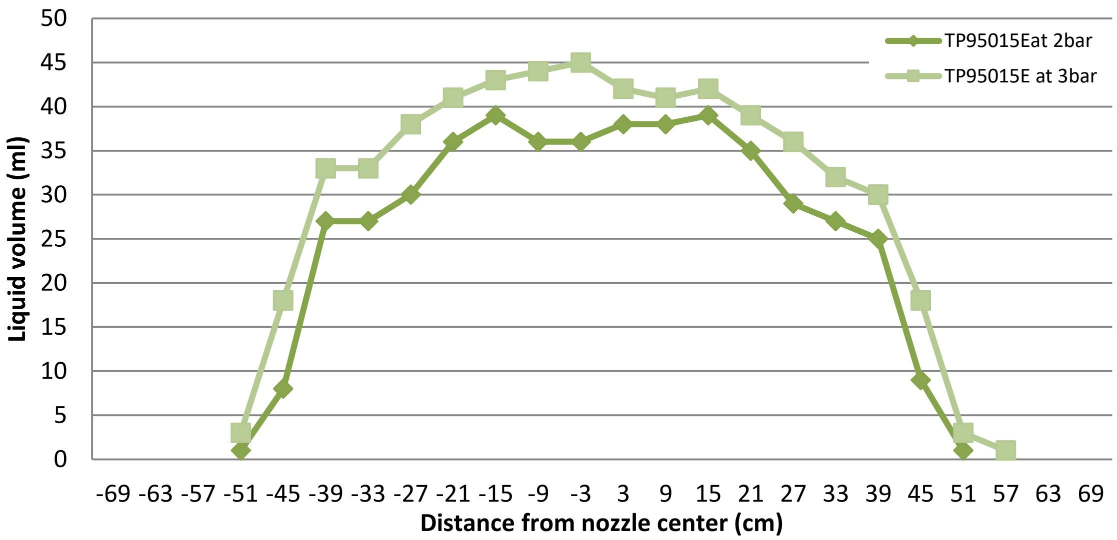

Fig. 4. Spray volumetric distribution for TP nozzle at pressures of 2 and 3 bar

The results in Figure 5 show spray distribution for different nozzle type, size and pressure combinations. The use of smaller sizes of the TP and DG nozzles gave good uniform of spray distribution at pressures 2 and 3 bar. Increasing the pressure from 2 to 3 bar increases the liquid volume under the nozzle. By increasing of DG nozzle size from 02 to 03 at pressures 2 and 3 bars, two big peaks appeared on the sides of the nozzle centre in comparison to the TP nozzle. Generally, Spray distribution of the TP nozzle was better than DG nozzle in all spray combinations because of reducing the differences in heights of the peaks under the nozzle.

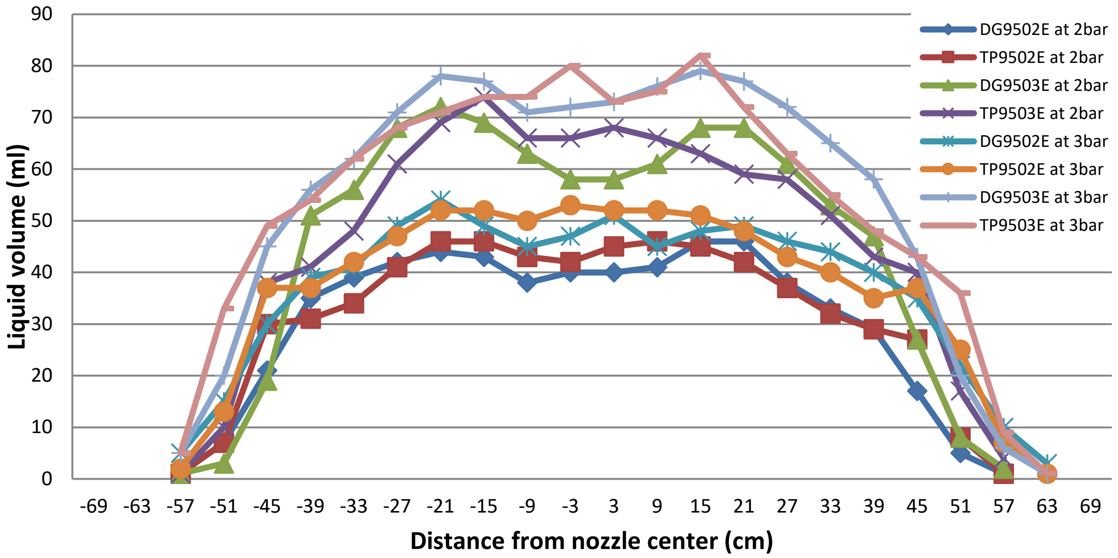

Fig. 5. Spray volumetric distribution for TP and DG nozzle sizes 02 and 03 at pressures of 2 and 3 bar

4. Conclusions

The results of this work typically showed important variations. The results indicated that DG nozzle behaviour is to some extent similar to that TP nozzle but additional variables like increase of spray width. Increasing of the nozzle size increases the liquid volume under the nozzle centre while an increase in the system pressure increases spray pattern width and improves the uniformity of the spray distribution.

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