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Full Length Research Paper

Nozzle type, angle and pressure effects on spray volumetric spread of broadcasting and banding application

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The ultimate goal of agricultural spraying application system is to put the correct amount of pesticides, in the correct place, at the correct time to reduce the pest to a level below the economic threshold in order to improve agricultural production. A spray patternator was fabricated for the selection of a suitable nozzle to have uniform distribution of the spray liquid. Experiments were conducted on a spray patternator through two types of spray nozzles (even flat fan nozzle TPE for banding application and standard flat fan nozzle TP for broadcasting application). Spray distribution was determined and compared by using single nozzle, at a height of 0.5 m under laboratory conditions. In addition, this paper examined the effect of spray fan angles 65 and 80° and liquid pressures 200 and 300 kPa on the spray distribution. The best distribution of the spray application was obtained by using banding nozzles, whereas the broadcasting nozzle gave an uneven spray distribution with a high peak just below the nozzle centre and taper off towards the edges of the spray pattern. For the two nozzle types tested, results revealed that increasing nozzle angle and pressure reduce the value of the coefficient of variation CV%.

Key words: Static spray distribution, nozzle, patternator, coefficient of variation (CV).

INTRODUCTION

Agricultural chemical can be applied according to the American Society of Agricultural and Biological Engineers (ASABE) Standards (2006) by broadcast application that uses spray over an entire field and band application that uses spray in parallel bands leaving areas between the bands free of chemical. Chemical control in row crops is typically carried out as a broadcast application by using standard flat fan nozzles and most farmers use this kind of application because it is the easiest and preferred method. In fact, standard flat-fan nozzles are not recommended for banded application as result to the following reasons: (1) These nozzles should be overlapped (a array of nozzles) to achieve spray uniform distribution across the entire width of the boom but using the overlapped spray in the row crop fields will cause losing of the spray among the rows or strips. (2) If these nozzles use without overlapping or as single nozzles above the parallel bands, the spray distribution will be uneven. However, management of the precision agriculture encourages reducing the use of pesticides in fields. The question is whether it is possible to use the existing even flat-fan nozzles for spray distribution in very narrow bands instead of standard flat fan nozzles to achieve more efficient spray distribution in the fields.

The technology of band spraying application has not been developed because broadcast applications are the preferred method. Very few publications on band applications and their equipment can be found and those available are with limited information as compared with broadcast application, (Williams, 1981). In modern agriculture, improving quality food production and reducing farming cost can be obtained by using suitable and correct applications. Band spraying is more economical as compared to broadcast spraying (Nigar et al., 2011) because it is targeting a specific area of the field such as rows or strips, amount of chemical used on a specific portion of the field area and reducing water use per area. Spraying application nozzle is designed to achieve good spray distribution and uniformity (Bahadir and Saim, 2011). According to the Spraying System Co (2011), even flat-fan nozzles are used to apply a uniform distribution across the entire spray pattern width. These nozzles should be used for banding applications over the strip or the row and should not be used for broadcast applications, (Spraying System Co, 2011; Vern and Elton, 2004). Wang et al. (1995) reported that uniformity of spray volumetric distribution is the most important indicator of the nozzle performance. Measuring the volumetric distributions of liquid from individual nozzle or group of nozzles have been investigated and identified by researchers using patternator under laboratory conditions (Krishnan et al., 1988; Ozkan et al., 1997; Lebeau et al., 2000; Womac et al., 2001; Sidahmed et al., 2004; Bayat and Yarpuz-Bozdogan, 2005; Javier et al 2008; Jean et al 2012). An even distribution of spray liquid is obtained by selecting suitable nozzles and calibrating them correctly (Lardoux et al., 2007). The objective of the present study was to examine the spray volumetric distribution and coefficient of variation (cv) for standard flat-fan nozzles and even flat- fan nozzles when used as a single nozzles for narrow-band spraying application using different nozzle angles and different liquid pressures.

MATERIALS AND METHODS

The nozzles selected for the study are standard flat-fan nozzles for broadcasting application and even flat- fan nozzles for banding application, these nozzles are classified according to International Organization for Standardization (ISO) of size 03 (0.3 gpm). This current research was carried out in laboratory of the university technology Malaysia (UTM). Before spray distribution measurements, the flow rate of each nozzle was tested by collecting the amount of water directly from the nozzle on a graded container at a pressure 300 kPa for one minute and measuring nozzle output with precision electric balance. Measurements were carried out at 26°C and 75% RH. Tests were repeated three times and the maximal deviation of all nozzles with nominal flow rate was ± 2.5%.

Static spray distribution test

Obtaining an even liquid-spray distribution is considered important in connection with row crop field application of pesticides, whether considering broadcast application or band spraying. Spray volumetric distribution of nozzle was determined in the laboratory by using a spray pattern analyzing system or patternator. The system was fabricate in UTM's workshop and contains a 300 cm long × 100 cm wide spray table with fifty (6 cm wide × 3 cm deep) V-shaped gutters. During the tests, the spray table was inclined 6° from the horizontal plane. Spray liquid was tap water. Water discharged from the nozzle was supplied from a 140 L pressured bottle, the pressured bottle was pressurized by a compressor and the pressure was adjusted by a pressure regulator. Static single nozzle was mounted on heights 50 cm above the spray table. In front of the table, a set of cylinders (250 mL) was used to collect the liquid from each channel. The weighting method was used to determine the transversal volumetric distributions collected during one minute by using a precision balance. Results of spray volumetric distribution were presented as (ml/min) at two nozzle pressures 200 and 300 kPa. This test was repeated three times.

Statistical analysis

The data from spray tests were collected to analyse the variance using a mathematical model for calculating the mean, standard deviation. The calculations made use of the statistical package of applications Microsoft Excel. The coefficient of variation was estimated by using the standard equation. $CV = \left(SD / X\right) \times 100$

Where: CV presents the coefficient of variation%, SD standard deviation and X the mean data. The analysis of variance (ANOVA) was performed on coefficient of variation to determine the effects of nozzle types, angles and pressures, and their interactions at the confidence interval was set at α = 0.05 using SPSS software version 20.

RESULTS

One of the most important requirements on agricultural boom sprayers is to produce a uniform distribution of the applied chemical on the target area. A series of laboratory measurements were conducted to examine the spray uniformity distribution. In total, 8 combinations of nozzle type, angle and pressure were tested corresponding with 24 measurements for standard flat-fan nozzles and even flat- fan nozzles.

Effect of nozzle type, angle and pressure on coefficient of variation (C.V %)

According to results of coefficient of variation in the Table 1 and analysis of variance Table 2 indicated that nozzle type, angle and pressure affect significantly on the spray uniformity distribution. The decreasing nozzle angle tends to increase the coefficient of variation of spray. As well as, increasing of nozzle pressure tend to give a good uniformity of dose. We can observe from Table 1 that the best value of coefficient of variation 42.73% was achieved by using nozzle TPE with angle 80° and at pressure 300 kPa. In general, even flat fan nozzle provided uniform distribution better than standard flat fan

Table 1. Effect of two nozzle types, angles and pressures on coefficient variation (CV).

Type of nozzle	Nozzle angle (°)	Nozzle pressure (kpa)	Coefficient of variation, CV (%)
TPE	80	200	44.10
		300	42.73
	65	200	58.60
		300	57.96
TP	80	200	68.16
		300	65.80
	65	200	74.44
		300	69.70

Table 2. Variance analysis of the effect of two nozzle types, angles and pressures on coefficient variation (CV).

Source	Type III sum of squares	df	Mean square	F	Sig.	Partial Eta squared
Corrected model	2876.926[a]	7	410.989	1481710.385	.000	1.000
Intercept	86962.874	1	86962.874	313520950.952	.000	1.000
nozzle	2091.469	1	2091.469	7540223.201	.000	1.000
angle	596.854	1	596.854	2151794.986	.000	1.000
pressure	31.061	1	31.061	111980.443	.000	1.000
nozzle * angle	143.253	1	143.253	516458.348	.000	1.000
nozzle * pressure	9.605	1	9.605	34628.735	.000	1.000
angle * pressure	1.017	1	1.017	3667.340	.000	.996
nozzle* angle* pressure	3.667	1	3.667	13219.643	.000	.999
Error	.004	16	.000			
Total	89839.804	24				
Corrected total	2876.930	23				

a. R Squared = 1.000 (Adjusted R Squared = 1.000).

nozzle throughout the flat spray pattern.

Effect nozzle type on spray distribution

According to Figure 1, it is clear that the type of nozzle has an important influence on the spray distribution. Banding nozzle TPE achieved the best spray volumetric distribution than broadcasting nozzle TP because the peak under the nozzle center became less acute as the result of increasing the height and size of the neighboring peaks around it and bind them together to reach the same height.

Effect nozzle type and pressure on spray volume distribution

The use of a high pressure instead of the low pressure improves the spray distribution. The spray nozzles TPE8003 and TP8003 at pressure 300 kPa gave better distribution than spray nozzles TPE8003 and TP8003 at pressure 200 kPa respectively as shown in Figure 2.

Effect of nozzle type and angle on spray volumetric distribution

Results in Figure 3, show that using nozzles having spray fan angles of more than 65° reduce spray peak under nozzle center. The spray nozzles TPE8003 and TP8003 gave better distribution than spray nozzles TPE6503 and TP6503 respectively and at the same pressure. Increasing nozzle angle from 65 to 80° reduced coefficient of variation for TPE from 58.60 to 44.10**%** more than the nozzle TP from74.44 to 68.16**%** as result to the reducing of the heights of the spray peaks under nozzle center.

Effect of nozzle type, angle and pressure on spray volume distribution

The effect of interaction of nozzle type, angle and pressure were also investigated. The interaction among these three factors affect the results of the spray

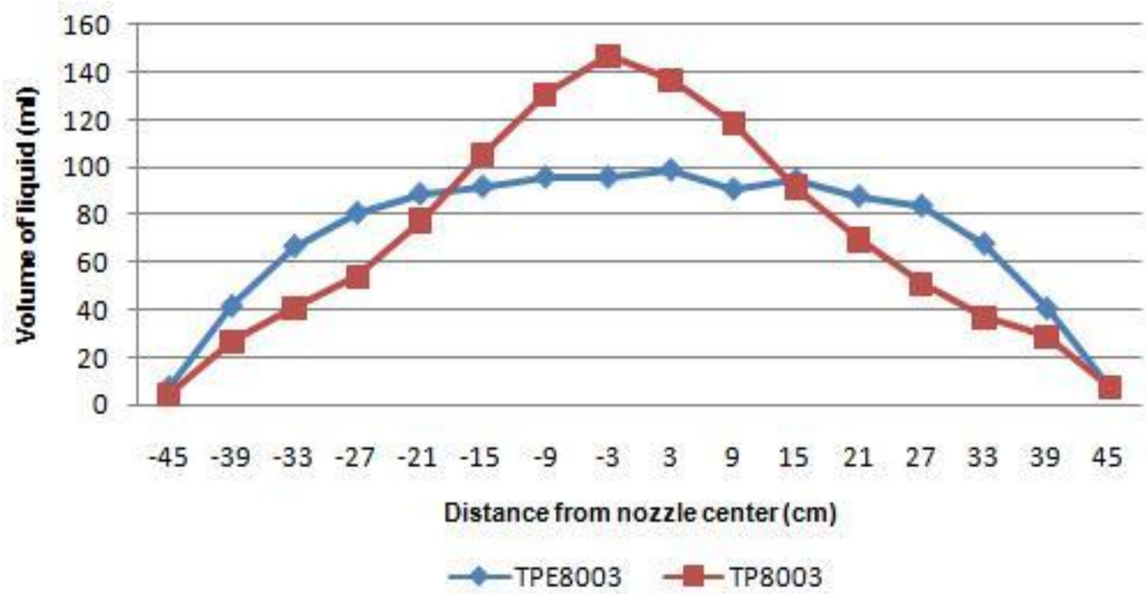

Figure 1. Spray volumetric distribution of two nozzle types TPE and TP at pressure 300 kPa.

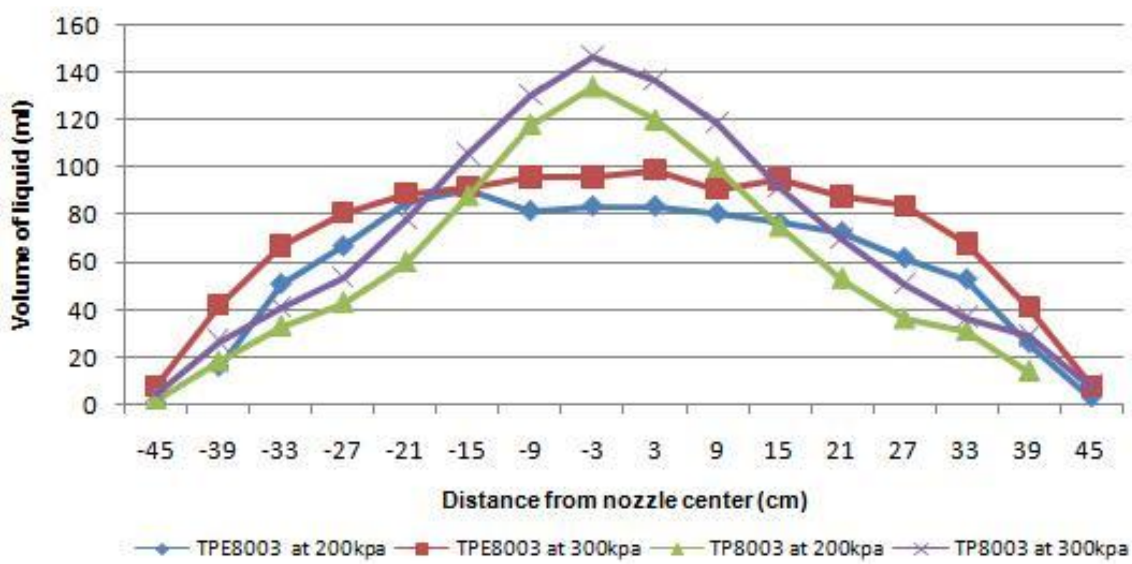

Figure 2. Spray volumetric distribution of two nozzle types TPE and TP at two nozzle pressures 200 and 300 kPa.

distribution and was noted from the static spray distribution test Figure 4 that even-spray flat-fan nozzles TPE were better than that of standard flat-fan nozzles TP in the spray distribution at the same nozzle angles and pressures.

DISCUSSION

A spray patternator was fabricated for the selection of a suitable nozzle type, its angle and pressure to provide uniform distribution of spray liquid above the plant. A spray analysis system or patternator measurement would probably be sufficient to accurately evaluate the static spray volumetric distribution. The two nozzles selected for this study were standard flat-fan nozzle normally recommended for broadcast spraying of pesticides in row-grown crops and even-spray flat-fan nozzle which was specially developed for band spraying. From laboratory experiments results, it was noted that the

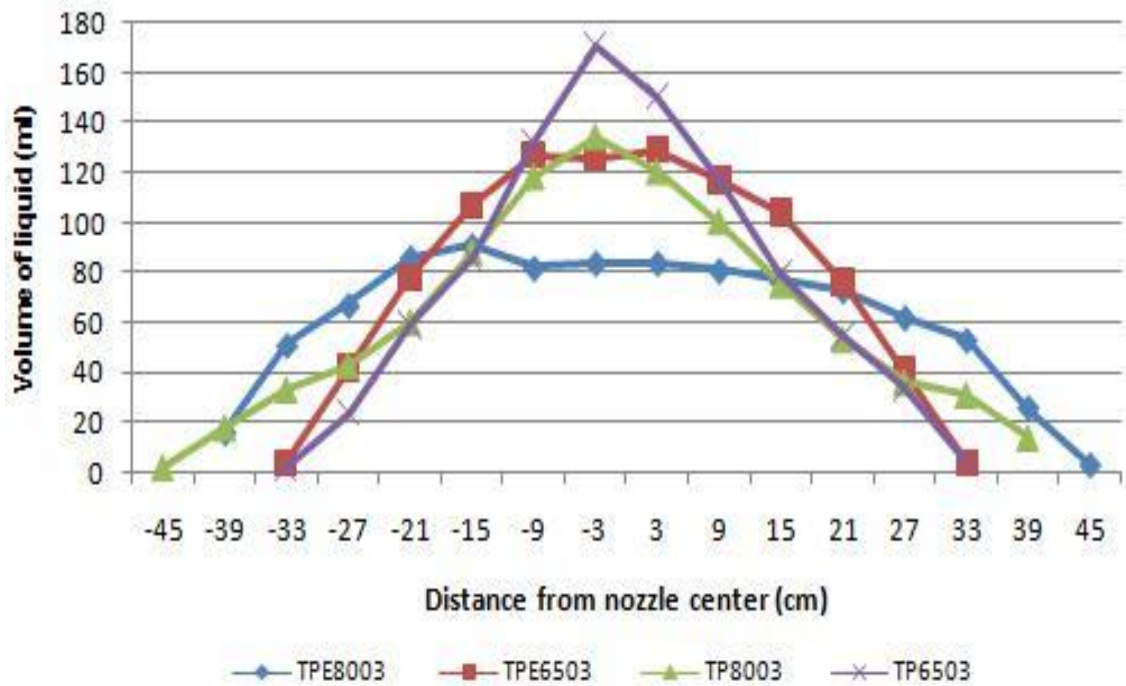

Figure 3. Spray volumetric distribution of two nozzle types TPE and TP with two nozzle angles 65 and 80° at pressure 200 kPa.

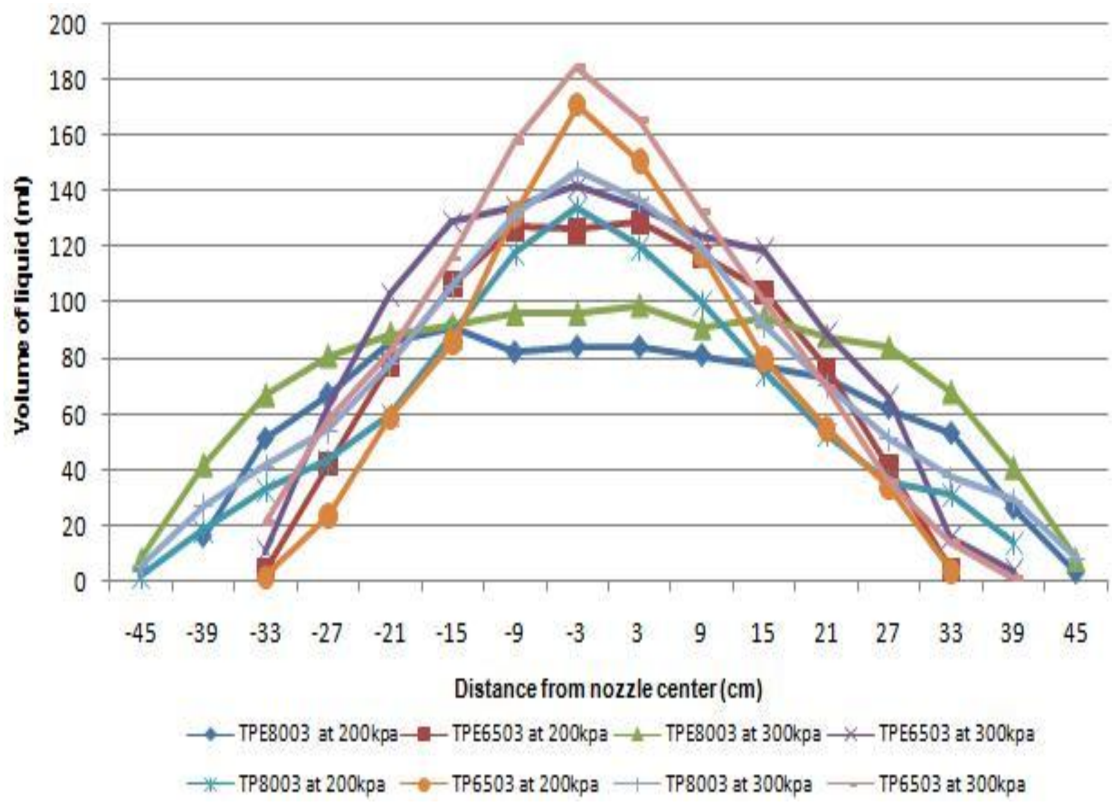

Figure 4. Spray volumetric distribution of two nozzle types TPE and TP with angle 65 and 80° and at two pressures 200 and 300 kPa.

banding nozzle gave the best spray uniformity with the minimum coefficient of variation at all nozzles angles and pressures. The results of the study showed that the combination of the nozzle type TPE, nozzle angle 80° and nozzle pressure 300 kPa gave the best spray volumetric distribution and minimum coefficient of variations 42.73%. Banding nozzle provide spray volumetric distribution better than broadcasting nozzle because they reduce height of the peak under the nozzle center by transferring part of the size of the liquid from the nozzle center and then distribute it at the nozzles sides. Increasing nozzle angle and pressure improve spray uniformity of all broadcasting and banding nozzles. This study supports the use of even flat nozzles in row crop spraying application as a means for improving spray distribution.

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