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Effect of Cross Wind, Nozzle Angle and Height on the Performance of Broadcasting Spraying System

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ABSTRACT

Spraying application system is used to spray pesticides to prevent or destroy pests which can harm crops. Crop protection products are dangerous chemical and must be applied with the utmost efficiency and minimum drift to prevent environmental pollution and save costs. This paper investigated the spray distribution and drift for broadcasting application using TeeJet flat-fan nozzle (TP) at three static nozzle heights 0.5, 0.75 and 0.90 m above spray patternator. To determine the total spray drift, wind tunnel was used to product three cross wind speeds 1, 2 and 3m/s. In addition, this paper also examined the effect of different spray fan angles 65°, 80° and 110° on spray drift particularly where there is need to make nozzle operates on the optimum heights above ground or plant level. According to the results of this study, the nozzle angle and height affected the spray volumetric distribution and drift. The wind speed had a high significant effect on the spray drift. The nozzle angle 65° gave the highest drift reduction compared to the other nozzle angles. The maximum drift for all nozzles was found at nozzle height of 90 cm. The minimum spray drift was found at wind speed of 1 m/s. This study supports the use of nozzle angles less than 110° on heights more than 0.5m and on wind speed more than 1m/s as a means for minimizing spray drift.

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INTRODUCTION

Agricultural pesticide application system faces challenges and problems such as spray distribution and drift as result to the combinations of mechanical factors of spray technique (nozzle angle and height) and environmental variable(wind speed) and their interactions. Evaluation of the spray volumetric distribution of the nozzles is the most important issue in a spray analysis and had been studied by several researchers [1-4]. In order to achieve optimum spray distribution pattern above ground or plant level, nozzle angle is one of the most important variables that can be used in determining the nozzle height above ground or plant level. According to Byron and Hamey [5], Miller *et al* [6], and Spraying System CO [7], nozzle angle of 110° should be used with nozzle heights of less than 50 cm and have become an adopted standard that to give a uniform volume distribution pattern.The assessment of spray drift is necessary to reduce the pollution of ecosystem, but it is particularly complex and very difficult to repeat spray drift measurements in the field with a high degree of reliability because weather conditions cannot be controlled [8-9], which was the major reason to develop wind tunnel protocols for the measurement of spray drift in controlled conditions.

Spray drift for various conventional flat-fan nozzles was investigated and compared under laboratory conditions[10]. Droplet size is an important factor for controlling spray drift to the non targeted areas. Reducing of the spray nozzle angle generally results in an increase in the droplet sizes generated and reduce drift [7]. Spray nozzle height above the ground or on top of the crop canopy is significant factor that influence the risk of drift, specifically when there is need to apply fine/medium spray qualities.The minimum possible nozzle height remains an important part of any drift control strategy. Spray drift from nozzle is a function of the nozzle height and the wind speed at the time of spraying. The use of flat fan angle 110° at heights of more than 50 cm increases the risk of drift [11]. Hobson *et al* [12] reported from computer simulation studies that nozzle heights of less than 50cm can be used with 110° nozzle angle and gives a better option for spray drift control than using nozzle has a narrower 80° spray angle and nozzle heights of 50 cm or more. Krishnan *et al* [13] used extended range fan nozzles of 110° above a patternator and found that wind velocity affected on spray pattern displacement. Sehsah *et al* [14] reported that the spray drift increased with increasing of the wind speed. The objective of this study is to examine the effect of spray nozzle angle and height on spray distribution and drift.

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MATERIALS AND METHODS

The nozzles selected for the study are standard flat-fan nozzles TP6503, TP8003, and TP11003. These nozzles are manufactured by Spraying Systems, Inc. (Wheaton, Ill.) for broadcasting application and classified according to International Organization for Standardization (ISO) of size 03(0.3gpm).Static tests for discharge rate were conducted for nozzles by collecting amount of water directly from nozzle on a graduated container atpressure 300 kPa for one minute and measuring nozzle output with precision electric balance. The spray liquid was tap water. Water discharged from the nozzle was supplied from a 140 L pressurized bottle, the pressure was provided by a compressor and the pressure was adjusted by a pressure regulator. Tests were repeated three times and a maximal deviation of all nozzles with nominal flow rate was ± 2.5%.

Spray volumetric distribution and the effective spray pattern width for nozzles were determined in the laboratory by using a spray pattern analyzing system or patternator. The system was fabricate in workshop of University Technology Malaysia (UTM) and contains a 300 cm length × 100 cm width spray table with fifty V-shaped gutters (with 6 cm width ×3 cm depth). During the tests, the spray table was inclined 6° from the horizontal plane. Static single nozzle was mounted on heights 50, 75 and 90 cm in the center of the spray table and at pressure 300 kPa. In front of the table, fifty tubes (250 mL) were 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 electric balance. Results of spray volumetric distribution were presented as (ml/min).After the spray pattern width was determined,wind tunnel was used to produce the cross wind speeds of 1, 2 and 3m/s to determine the total spray driftas shown in Figure 1.

Fig.1: Experimental setup in the wind tunnel to determine spray drift from flat fan nozzle TP.Patternator 300 cm length × 100 cm width spray table with fifty V-shaped gutters (6 cm width ×3 cm depth).

The total spray drift from spray nozzle above patternator was calculated from the following equation [15]

$$D = 100\left[1 - \frac{\sum_{i=1}^{i=N} V_i}{Q_o}\right] \quad (1)$$

Where D represents drift percentage (%), i represent the test tube index; N the total number of test tubes, Vi the water quantity collected in the test-tube (ml/min) and Q_o the nozzle flow rate. This test repeated three times. Measurements were carried out at an average temperature 31C° and an average relative humidity RH 79%. The calculations made use of the statistical package in Microsoft Excel.The data from spray tests were collected and analysis of variance (ANOVA) on spray drift was carried out, using a mathematical model for a completely randomized design.The F test was used to evaluate the significance of factors nozzle type, height and wind speed in the model, their interactions at the significance level 0.05 confidence intervals were determined to be 95.0%using SPSS software version 20.

RESULTS AND DISCUSSION

The spray volumetric distribution sometime is unimodal that is triangular shaped. In general;the nozzles gave spray distribution with a peak just below the nozzle centre and less spray towards the edges of the spray swath.Figure 2 shows that the use of the nozzles having spray fan angles of less than 110° will increase thespray peak under the nozzle center. The nozzle angle 65° gave the highest peak with volume 185 ml at height 50cm and just below the nozzle centre.

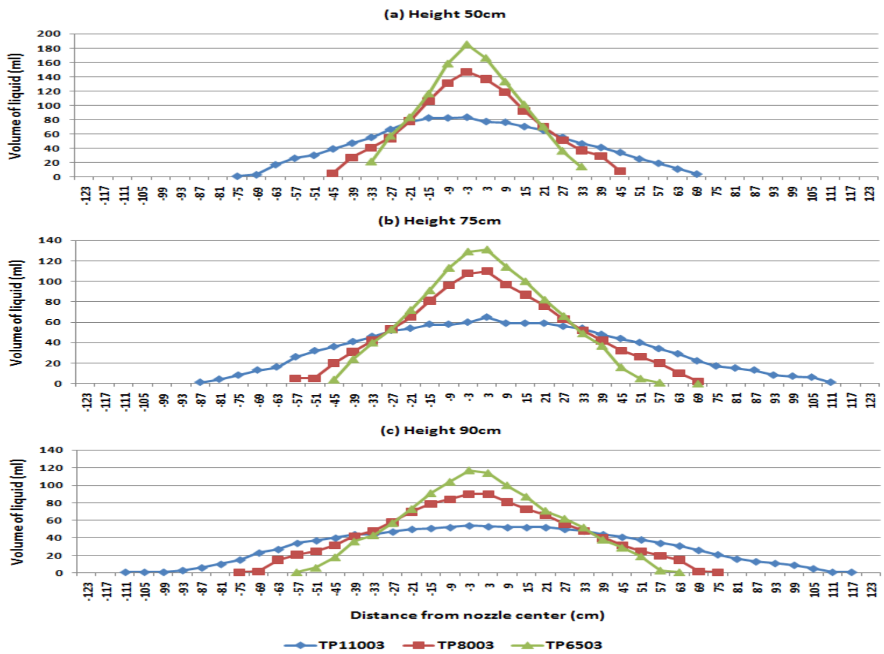

Fig. 2: Spray volumetric distribution (ml) for three nozzle angles110°, 80°, and 65° at heights 50, 75and 90cm.

According to the results of analysis of variance table 1,the nozzle angle, height and wind speed and their interactions affected significantly on the spray drift.

Table 1: Variance analysis of the effect of nozzle angle, height and wind speed on spray drift.

source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	21215.541	1	21215.541	757330.576	.000	1.000
angle	2485.860	2	1242.930	44368.846	.000	.999
height	2416.099	2	1208.050	43123.713	.000	.999
wind	6809.827	2	3404.913	121545.100	.000	1.000
angle * height	191.738	4	47.934	1711.113	.000	.992
angle * wind	656.445	4	164.111	5858.275	.000	.998
height * wind	885.243	4	221.311	7900.123	.000	.998
angle * height * wind	39.207	8	4.901	174.946	.000	.963
Error	1.513	54	.028			
Total	34701.473	81				
Corrected Total	13485.932	80				
Corrected Model	13484.419[a]	26	518.632	18513.574	.000	1.000

R Squared = 1.000 (Adjusted R Squared = 1.000)[a]

Results of the wind tunnel experiments showed that the use of nozzles with smaller spray fan angles reduced the spray driftas result to increase droplet sizesas shown inFigure 3. The similar results were observed by Spraying System CO [7]

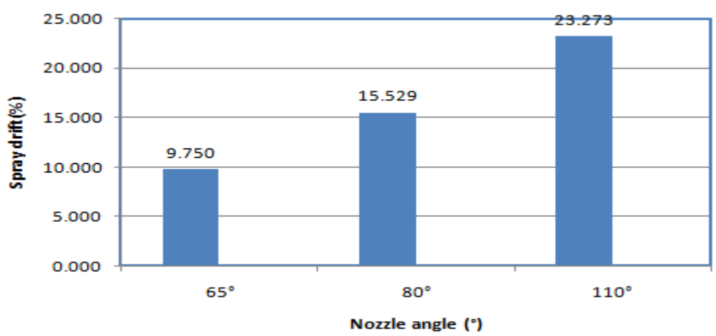

Fig. 3: Effect of the nozzle angles 65°,80° and 110° on spray drift.

The volume of the spray liquid collected on the patternator increased markedly with reducing of the nozzle height as expected. The average of the lowest value of spray drift 9.009% was found at nozzle height 50cm as

shown in Figure 4.The droplets fall down quickly when the nozzle height is low. These results were observed by Miller *et al.*, [11].
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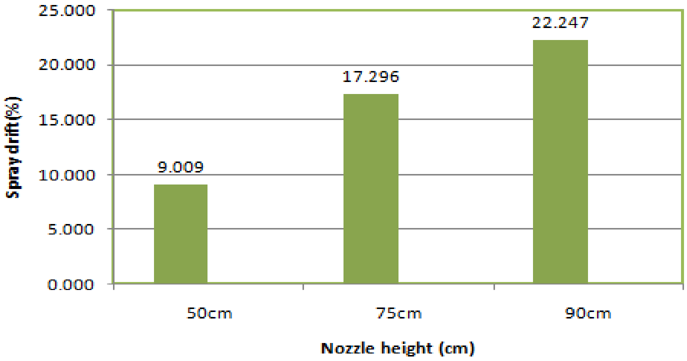

Fig. 4: Effect of the nozzle heights 50, 75 and 90cm on spray drift.

Figure 5 shows that the wind speed significantly affected the spray drift in which the wind speed 3 m/s in comparison to the 1 and 2 m/s increased 448.8% and 70.7% in spray drift respectively.The droplets have no chance to move away the target when the cross wind speed is weak. These results were observed bySehsah *et al.*,[13].

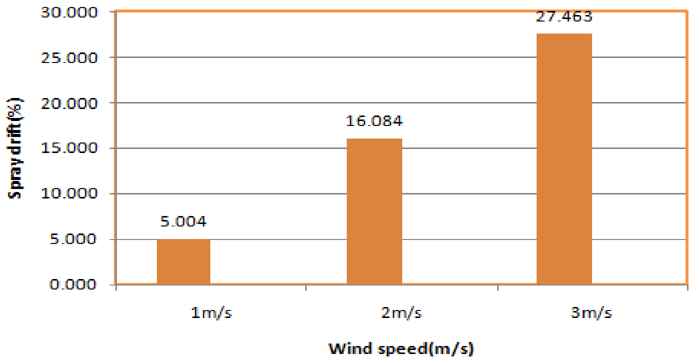

Fig. 5: Effect of the wind speeds 1, 2 and 3m/s on spray drift.

The interaction of nozzle angle 65° and nozzle height 75cm in comparison to the interaction nozzle angle 110° and nozzle height 50cm achieved 21.65% less spray drift as shown in Figure 6. These results were observed by Miller *et al.*,[11].

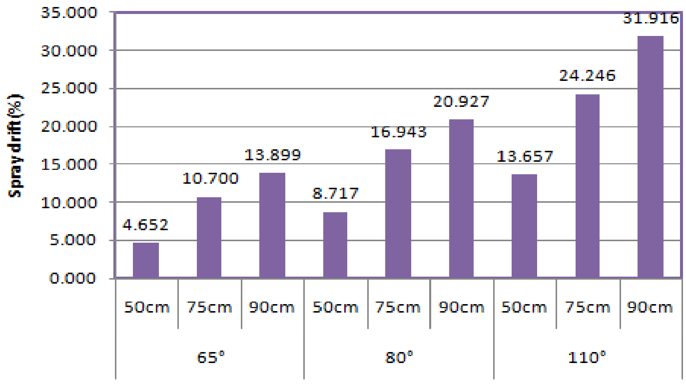

Fig. 6: Effect the interaction between the nozzle angles 65°, 80° and 110°and nozzle heights 50, 75 and 90cm on spray drift.

Figure 7 shows the combination of nozzle angle 65° and wind speed 3m/s in comparison to thecombination of nozzle angle 110° and wind speed 2m/s achieved 24.65% less spray drift.

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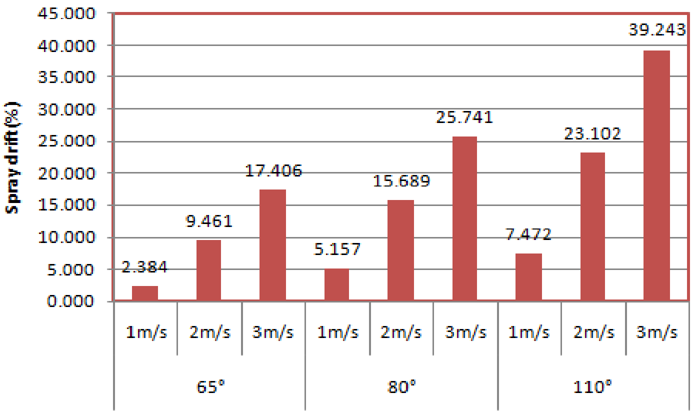

Fig.7: Effect the interaction between nozzle angle 65°, 80° and 110° and wind speeds1, 2 and 3m/s on spray drift.

According to the Figure 8, the combination of nozzle height 50cm and wind speed 3m/s in comparison to the combination nozzle height 90cm and wind speed 2m/s achieved 32.79% less spray drift.

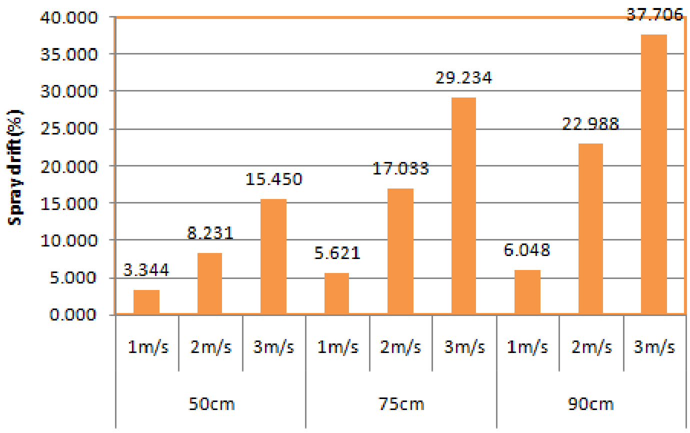

Fig. 8: Effect the interaction between nozzle heights 50,75 and 90 cm and wind speeds1,2 and 3m/s on spray drift.

It is clear that interaction of the nozzle angle 65° and nozzle height 50cm and wind speed 1m/s achieved the lowest spray drift 2.20% in comparison to the all combinations as shown in Figure 9.

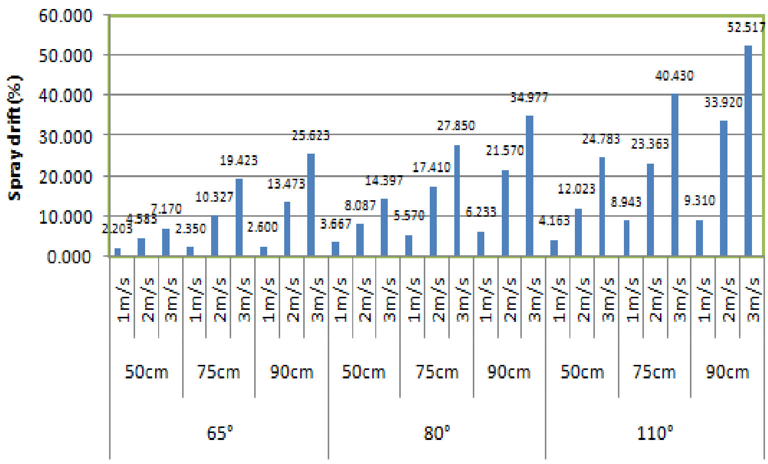

Fig. 9: Effect the interaction between the nozzle angles 65°, 80° and 110° and nozzle heights 50,75 and 90 cm and wind speeds1, 2 and 3m/s on spray drift.

Conclusion:

Veryfew of practicaldetailed studies had examined and focusedon the factors affect spray distributionanddrift. In this study, nozzle angle and heightwere proposed as tool to reduce spray drift. The results of this paper provide experimental basis to set up a simulation platform to evaluate total spray drift. The adopted protocol provides consistent values of the deposits on a patternator. It was noticed that spraying conditions significantly affected spray drift. Results of this paper showed that the risk of drift can be reducing by using of nozzles having spray fan angles of less than 110° at heights of greater than 50cm. However, the use of the minimum possible nozzle height remains an important part to control spray drift.

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