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Performance evaluation of different orifice size of nozzle on spray patternator

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Abstract
Sprayer is an equipment used for spraying liquid, especially a substance used to kill insects that damage crops. A spray nozzle is a device that facilitates the dispersion of a liquid by the formation of a spray. The objective of this study is to determine the effect of operating pressure (A), orifice size (B) and height of spray (C) on uniformity of distribution of developed portable knapsack boom power sprayer. The observations were analyzed by using completely randomized design (CRD) test. It was found that the uniformity of distribution was more as the pressure increased from 3 to 6 kg cm^{-2} at height of spray from 30 to 60 cm. Orifice size of 1 mm gives better uniformity of distribution at 45 cm height of spray and 6 kg cm^{-2}. The results shown that uniformity of distribution concentrated more in the centre of the patternator and gradually decreased as distance increased from centre of the patternator. The uniformity of distribution varied with different orifice size. This is probably due to the behavior of nozzles of different spray angels. It was found that orifice size is very important parameter which affect the distribution of pattern (CV) The low value of coefficient of variation represents an indicator for good uniformity distribution.

Keywords: Orifice size, nozzle, spray patternator

Introduction

Pesticides are critical inputs for crop production worldwide and are expected to continue to play a major role for the foreseeable future to protect most crop systems from the infestation of insect pests and diseases. A large volume of pesticides is used in crop protection, however, its application on different crops is highly inefficient. Misapplication, evaporation, leaf runoff and drift during the process of spraying results in loss of a major portion of these chemicals. The unused and lost portion of pesticides, which may be to the extent of 90% of the applied chemical, not only results in economic loss but it also pollutes air, water and soil.

Insect pest continues to cause losses of yield and quality either directly by feeding or indirectly as a vector of disease. These losses can be extremely serious and may result in total loss of a crop in some fields. The effectiveness, cost and safety of any pest control program are often greatly influenced by the distribution of the pest control agent. Many pest control applications are made with little knowledge of the variation of the pest control agent on the target. To improve pest control applications, instrumentation is needed accurately and rapidly to determine the distribution of sprays across the swath for various nozzle operation conditions (Mahmood, 2003) [3].

The major reason for pesticide loss is use of inefficient spraying machines, which are unable to maintain specified nozzle pressure, nozzle discharge, nozzle height that affects spray pattern, droplet size, spray uniformity *etc.* Usually the amount of liquid sprayed is metered at the nozzle. The nozzle is one of the most important parts of a sprayer, yet it is often neglected and seldom checked to ensure that expensive chemicals are being applied at correct rate (Matthew, 1992) [4].

The spray uniformity distribution is affected by the nozzle aperture diameter, fluid pressure, cone angle and distance from the target. Uniformity of volumetric distribution is the most important indicator of the nozzle performance (Wang *et al.*, 1995) [7]. So it is necessary to study the influence of orifice size of nozzle on uniformity of distribution. The portable knapsack boom power sprayer was developed in the Department of Farm Machinery and Power Engineering, UAS, Raichur, Karnataka. This paper describes effect of operational parameters such as operating pressure, orifice size of nozzle and height of spray on uniformity of distribution.

Material and Methods

This study was conducted to know the effect of operating pressures (3, 4.5 and 6 kg cm^{-2}) and orifice size (1, 1.5 and 2 mm) at three height of spray (30, 45 and 60 cm) on uniformity of distribution of spray in the laboratory. Hollow cone type nozzle was selected for the study. The laboratory evaluation of developed portable knapsack boom power sprayer was carried out in the Department of Farm Machinery and Power Engineering, UAS, Raichur, Karnataka.

Spray patternator

A patternator quantifies the spatial location of the drops emitted from a sprayer and visualizes the patterns of sprays. The spray patternator consists of number of channels aligned perpendicular to the nozzle spray and can be of any convenient length provided that it encompasses the area of the spray. A constant pressure regulator and a pressure gauge is placed as close to the nozzle as possible to maintain uniform pressure. Adjustments are provided to hold the nozzle at a certain height during spraying. Collecting tubes are provided to collect the water from the channels during spraying. The nozzle shall be given a preliminary run until a constant flow rate from the patternator has been achieved and then the readings are taken (IS: 8548-1997). The spray patternator gives swath uniformity of a nozzle or boom which can be known just through visual observation. The spray patternater as shown in the figure 1.

Uniformity of distribution

Spray uniformity is considered as an essential factor in determining the effectiveness of the spraying. In spray applications for crops, the spatial distribution of leaves, fruits or other parts of the plant may vary considerably depending on the crop, growing system, growth stage, purpose of the application or other factors. Therefore, uniformity of the spray should be found in order to provide a good deposition uniformly over the whole height of the crop canopy. The uniformity of the spray distribution across the boom or within the spray swath is essential to achieve maximum chemical effectiveness with minimal cost and minimal non target contamination. The uniformity of the nozzles was calculated by using spray patternator.

The nozzles were mounted at the center of a metallic frame and its axis was kept perpendicular to the horizontal (Figure 2). The height of the nozzle assembly was also adjustable as holes were provided in the other vertical frame (Figure 3). The nozzles were run at different pressures of 3, 4.5 and 6 kg cm^{-2} and heights of 30, 45 and 600 cm and orifice size of 1, 1.5 and 2 mm to check nozzle's uniformity of distribution at different heights, since for different crop heights boom height also changes. The collected spray liquid from the channels was poured to measuring jars and the readings were taken. The test was run for one minute each and replicated for three times and the average data was calculated. Liquid collected at each channel was noted.

Fig 1: Spray patternator

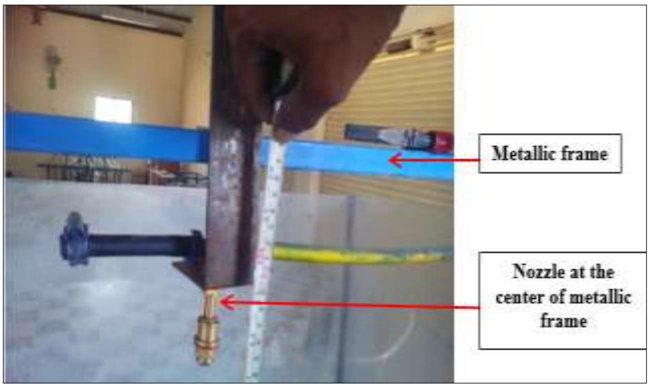

Fig 2: Nozzle mounted at the center of a metallic frame

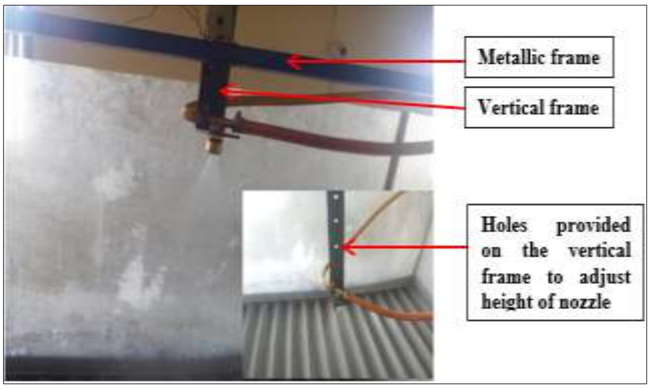

Fig 3: Adjustment of height of nozzle on the spray patternator

The distribution was measured by directing the spray on 16 channeled table with calibrated collection tubes at the ends of the channels. Each channel has a width of 100 mm and a depth of 75 mm, all inclined at an angle of 15 degree to the horizontal. Spray liquid used was tap water. The nozzle was mounted at selected level of height and was sprayed vertically landing on the equidistance grooves eventually getting separated into different channels which flows down due to the inclination of the table. At the end of the channel sprayed water is directed into its respective graduated cylinder situated at the base (Figure 4). The height of water was measured at the end of each experiment and recorded from the graduated cylinders. Nozzle was operated by changing the orifice size at different operating pressure and height of spray. One nozzle was used for the patternator study and the rest one nozzle was used to measure its uniformity in discharge. (IS: 8548-1997).

Fig 4: Spray liquid from the channels collected in the measuring jars

Results and Discussions

Nordby (1978) [5] suggested that atomizers should evaluate on the basis of their coefficient of variance. The less coefficient of variance indicated the even spray distribution. The effect of operational parameters *viz.*, operating pressures (3, 4.5 and 6 kg cm^{-2}), orifice size (1, 1.5 and 2 mm) and height of spray (30, 45 and 60 cm), on uniformity of distribution of spray was analyzed using completely randomized design (CRD) test and statistical software package Design Expert. [version 10.0.4 for windows, Stat-Ease, Inc.,] and results are presented below.

The effect of operating pressure (A), orifice size (B) and height of spray nozzle(C) on coefficient of variation of uniformity of distribution is presented in table 1. From the table 1, it is observed that the coefficient of variation decreased by increasing the operating pressure and orifice size, from 3 to 6 kg cm^{-2} and 1 to 2 mm respectively. The coefficient of variation increases as the height of spray increased from 30 to 60 cm. The CV of hollow cone nozzle of orifice size 1mm varies from 48.2 to 43.6%, when the pressure changed from 3 to 6 kg cm^{-2} at height of spray of 30 cm. whereas for orifice size 1.5 mm and 2 mm CV was found between 44.5 to 39.4% and 39.7 to 34.7%, when the pressure varied from 3 to 6 kg cm^{-2}, respectively at height of spray 30 cm. The hollow cone nozzle of orifice size 2 mm has less CV compared to orifice size 1 mm and 1.5 mm. The maximum CV was obtained for the orifice size 1 mm *i.e* 48.2% at the operating pressure of 3 kg cm^{-2} and 30 cm height. But in the case of orifice size 2 mm the CV was minimum *i.e*. 34.7% at an operating pressure of 6 kg cm^{-2} at spray height of 30 cm.

It is observed that CV at 3, 4.5 and 6 kg cm^{-2} of operating pressure in hollow cone nozzle of orifice size 1 mm for 30 cm height of spray was found to be 48.2, 45.3 and 43.6%, whereas for 45 cm height of spray the values were 49.8, 46.5 and 45.1% following 51.4, 48.1 and 46.3% at 60 cm height of spray. For the orifice size 1.5 mm at 30 cm height of spray was found to be 44.5, 41.5 and 39.4% whereas for 45 cm height of spray the values were 45.7, 42.9 and 40.5% following 47.2, 45.2 and 42.1% at 60 cm height of spray. For the orifice size 2 mm at 30 cm height of spray was found to be 39.7, 36.8 and 34.7% whereas for 45 cm height of spray the values were 41.2, 38.3 and 36.2% following 42.5, 39.8 and 37.4% at 60 cm height of spray.

The variation among the different orifice size of hollow cone nozzle was calculated and the coefficients of variation for all the pressures were around 2.60% which is acceptable.

Table 1: Effect of operating pressure, orifice size and height of spray nozzle on uniformity of distribution in terms of coefficient of variation

Sl. No.	Operating pressure (A), kg cm^{-2}	Orifice size (B), mm	Coefficient of variation% Height of spray nozzle(C), cm		
			30	45	60
1	3	1	48.2	49.8	51.4
		1.5	44.5	45.7	47.2
		2	39.7	41.2	42.5
2	4.5	1	45.3	46.5	48.1
		1.5	41.5	42.9	45.2
		2	36.8	38.3	39.8
3	6	1	43.6	45.1	46.3
		1.5	39.4	40.5	42.1
		2	34.7	36.2	37.4

The analysis of variance (table 2) of CV showed that the main effect of each factor of operating pressure (A), orifice size (B) and height of spray (C) significantly influenced the CV. The interaction effects of (A×B), (B×C), (A×C) and (A×B×C) also influenced the CV at 1 percent of level of significance.

Table 2: Analysis of variance for Coefficient of variation of uniformity of distribution

Source	Sum of Squares	DF	Mean of square	F Value
Model	1466.84	26	56.42	45.30 **
A-Operating pressure	338.50	2	169.25	135.89 **
B- Orifice size	1009.02	2	504.51	405.07 **
C-Height of spray nozzles	115.38	2	57.69	46.32 **
AB	1.90	4	0.48	0.38 **
AC	0.680.52	4	0.17	0.14 **
BC	0.84	4	0.13	0.11 **
ABC	64.76	8	0.10	0.084 **
Residual	73.11	52	1.25	
Cor Total	1604.71	80		

** = Significant at 1% level, NS = Non significant

Std. Dev.	1.12	R-Squared	0.9577
Mean	42.96	Adj R-Squared	0.9366
C. V.%	2.60	Pred R-Squared	0.8974
Press	157.15	Adeq Precision	28.416

The effect of operating pressure, orifice size and height of spray on CV at 3, 4.5, and 6 kg cm^{-2} and different orifice size of hollow cone, 1 mm, 1.5 mm, 2 mm for different height of spray 30, 45 and 60 cm has been presented in the Fig 5, 6 and 7. It was found that increased operating pressure and orifice size gives less CV *i.e* indicated best even distribution of spray. So that the uniformity of distribution was more as the pressure increased from 3 to 6 kg cm^{-2} at orifice size from 1 to 2 mm. which may be due to the fact that discharge of the sprayer increased as pressure increases. From the statistical analysis of these parameter data, it was shown that spray distribution is improved by increasing nozzle size, pressure and reduces the nozzle height. The orifice size is very important parameters which affect the distribution of pattern (CV). This is probably due to the behavior of nozzles of different spray angels. The low value of coefficient of variation represents an indicator for good uniformity distribution. Similar results were reported by Sehsah and Kleisinger (2009) [6], Bahadir and Bastaban (2011) [1].

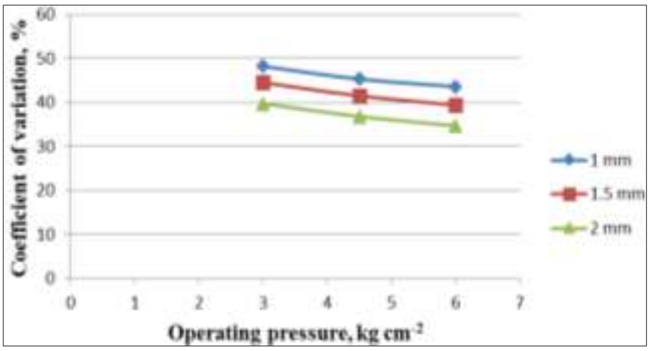

Fig 5: Effect of operating pressure, orifice size on uniformity of distribution in terms of coefficient of variation at 30 cm height of spray nozzle

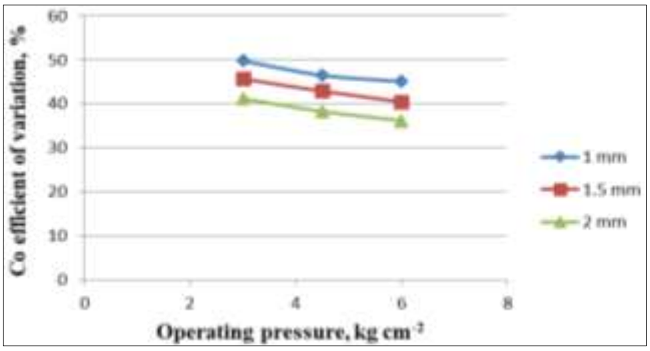

Fig 6: Effect of operating pressure, orifice size on uniformity of distribution in terms of coefficient of variation at 45 cm height of spray nozzle

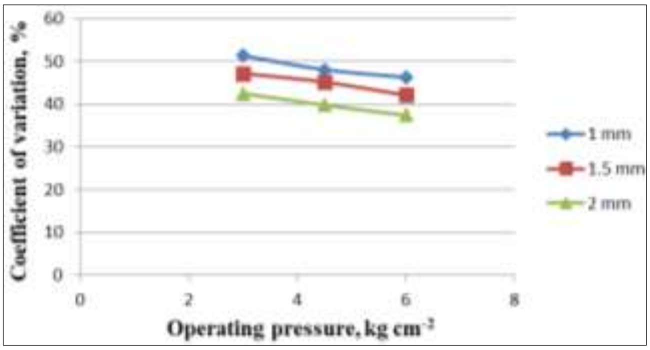

Fig 7: Effect of operating pressure, orifice size on uniformity of distribution in terms of coefficient of variation at 60 cm height of spray nozzle

Conclusions

The portable knapsack boom power sprayer was tested in the laboratory. For evaluating the uniformity of distribution, spray patternator was used. The discharge was collected from channels of spray calibrator at 30, 45 and 60 cm height of spray. The uniformity of distribution at selected levels of operating pressures (A), orifice size (B) and height of spray (C) were analyzed using completely randomized design (CRD) test. It was found that uniformity of distribution concentrated more in the centre of the patternator and gradually decreased as distance increased from centre of the patternator. Results shown that the uniformity of distribution was more as the pressure increased from 3 to 6 kg cm^{-2} at height of spray from 30 to 60 cm. Orifice size of 1 mm gives better uniformity of distribution at 45 cm height of spray and 6 kg cm^{-2}. The uniformity of distribution varied with different orifice size. This is probably due to the behavior of nozzles of different spray angels. From the study it can be concluded that orifice size is very important parameters which affect the distribution of pattern (CV). The low value of coefficient of variation represents an indicator for good uniformity distribution.

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